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WORKPLAN FOR COMPREHENSIVE WATER AND LOAD BALANCE STUDY, QUESTA MINE, NEW MEXICO

(MINE & TAILINGS FACILITY CLOSEOUT PLAN PROGRAM TASK A11 – PHASE 1-4)

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1 INTRODUCTION

1.1 Terms of References

On September 21, 1999, Molycorp Inc. filed an application with the Mining and Minerals Division (MMD) of the Energy, Minerals, and Resources Department of New Mexico for extension of time for approval of a closeout plan for the Questa Mine, New Mexico, under Permit No. TA001RE. At the request of Molycorp, Robertson GeoConsultants Inc. (RGC) prepared a schedule for milestones and deliverables for the period December 1999 until anticipated approval of the Closeout Plan. This schedule was submitted to the MMD by Molycorp in support of the time extension application on November 15, 1999. This schedule outlines the supporting studies and reports as well as the public review program required for preparation and submission of a Closeout Plan for the Questa Mine and tailings Facility by January 31, 2001 (Appendix A). Molycorp's application for the time extension for approval of a closeout plan for the Questa Mine was approved by the MMD on December 30, 1999.

The submitted schedule provides for several work plans on a Comprehensive Hydrological Balance Study (Task A.11 of Work Schedule for Mine Site and Task A.3 of Work Schedule for Tailings Facility; see Table A1 & A2 of Appendix A, respectively) to be submitted to the MMD by January 31, 2000. The present workplan has been prepared on behalf of Molycorp to satisfy this requirement. Note that the four individual work plans listed in Table A1 and A2 (one each for Phases 1–4 of Task A11) have been combined here into a single, comprehensive work plan.

1.2 Rationale for Load Balance Study

Molycorp has to submit a closeout plan for the Questa Mine by January 2001. In order to develop cost-effective closeout measures that are protective of the environment, the current and potential future impact of the mining related ARD sources (mine rock piles, open pit walls and underground workings) on the Red River system (surface water and groundwater) ecosystem will have to be understood.

A large body of study is available on the water quality and aquatic biota of the Red River. The data generally suggest a degradation in downstream water quality, and increased metal loadings in the sediments of the Red River in the reach between the town of Red River and the Ranger Station (downstream of the Questa Mine). However, there is debate as to the relative contributions of natural acid rock drainage (ARD) from mineralized rock and associated erosional scars versus ARD from the mine rock (mineralized mine rock and workings) to the Red River. An assessment of the Red River water quality is further complicated by large variations in streamflow and contaminant loads due to long-term climate variations as well as diversion of stream water and groundwater from the Red River system (for use in the mill).

The proposed load balance study is designed to synthesize all existing data on climate, stream flow and water quality in order to develop a credible and defensible model of how contaminants are routed through the basin and reach the Red River. The model will include all potential sources (both natural and mining-related) and will be calibrated over a sufficiently long time period (at least 30 years) to account for past mine developments (and associated changes to the water balance of the Red River system) as well as long-term climate variations.

The calibrated load balance will provide a tool for evaluating alternative closure measures and their impact on the stream water quality and by extension on the overall ecological health of the Red River.

1.3 Objectives of Load Balance Study

The load balance study has three principal objectives

- develop a comprehensive load balance of ARD derived contaminants (sulfate, Al and other metals) for the Red River basin accounting for natural sources outside the mine area (non-mining scar areas), natural sources (scar areas and mineralized bedrock) within the mine area as well as mine-related sources (mine rock piles and underground workings);

- determine the temporal variations in ARD loading to the Red River from natural and mining sources due to climate variations and mining operation;

- evaluate the effect of alternative closeout measures (e.g. revegetation, re-sloping, re-location etc.) on Red River water quality.

The following section outlines the overall approach of the load balance study and introduces some of the models proposed for this work. The detailed work plan for the study is presented in Section 3.

2 APPROACH TO LOAD BALANCE STUDY

The water quality regime of the Red River basin depends on various hydrologic, physical, chemical and biological processes. Numerous studies have been undertaken over the years to try to understand these processes. This has resulted in many insights, but many questions still remain or have been inadequately addressed. Some of the more important questions revolve around the following issues:

- identification of the sources of contamination to the Red River;
- quantification of the chemical loads generated by these various sources;
- identification of the pathways by which the contaminants reach the river; and
- chemical reactions occurring along the flow path and within the Red River.

A review of past studies suggests that the water quality regime of the Red River is complex. One effective way of analysing a complex system is to develop a numerical model of it. Development of such a model will be an integral part of the Closeout Plan studies. This work plan describes the steps that will be undertaken to develop the model, which will cover the entire Red River basin, but will have particular focus on the mine site proper, the tailings impoundment, the hydrothermal scar areas, and the middle reach of the Red River from the Town of Red River to the Questa Ranger Station.

No single numerical model is available to handle all of the complexities associated with the Red River system. Accordingly, the proposed "model" of the system will actually be an assemblage of a number of different models, some developed by government agencies and others developed specifically for this project. Table 1 presents a framework for the modelling that will be done. A total of eight models are planned. Each model is defined as a combination of a certain numerical model and a certain area to which the model will be applied. A total of four numerical models will be utilized. The three models developed by government agencies are described below. Details on the spreadsheet models are presented later in Section 3.

2.1 Hydrological Simulation Program – Fortran (HSPF)

HSPF is a set of computer codes that can simulate the hydrologic and associated water quality processes on pervious and impervious land surfaces and in streams and well-mixed impoundments (Bicknell et al., 1997). Two government agencies have been involved in the development of this model: the U.S. Environmental Protection Agency (USEPA) and the U.S. Geological Survey (USGS). The first version of the program was released in the 1970's and has since undergone many upgrades. The latest upgrade, known as Version 11, was released in 1996. HSPF has a long track record and has been used in hundreds of applications around the world. The USEPA and the USGS have independently developed graphical interface programs to facilitate operation of the HSPF model. The EPA version is known as BASINS 2.01 (for details visit their web page at www.epa.gov/docs/ostwater/BASINS). The USGS version is known as GENSCN (for details visit water.usgs.gov/software/genscn.html).

The HSPF model can be thought of as comprising two components, one for hydrologic processes and the other for water quality processes. Each is described below under separate headings.

2.1.1 Hydrologic Component

The hydrologic component of the HSPF model is a conceptual representation of the land-based portion of the hydrologic cycle. Inputs comprise calibration parameters, physical features of the study basin and of the stream reaches, point source discharges, point source abstractions, and meteorological data. The required meteorological data are: (i) precipitation, (ii) potential evapotranspiration, (iii) air temperature, (iv) dewpoint temperature, (v) and (vi) solar radiation. Through a series of mathematical functions that represent the different components of the hydrologic cycle, the model simulates streamflow hydrographs at specified locations within the study basin.

HSPF contains conceptual representations of the following components of the hydrologic cycle: (i) interception, (ii) soil moisture, (iii) surface runoff, (iv) interflow, (v) baseflow, (vi) snowpack depth and water content, (vii) snowmelt, (viii) evapotranspiration, and (ix) groundwater recharge. There is a certain degree of empiricism in all of the conceptual representations; accordingly, the model must be calibrated for each study basin. This means that the calibration parameters must be adjusted so that the output from the model (i.e., simulated hydrographs at a number of specified points) matches reasonably well with the observed records of streamflow at those same points. The model should also be made to reproduce the development and subsequent ablation of the snowpack in the study basin, as measured by one or more snow courses.

The model has a number of functions that allow the effect of human activity on streamflows to be simulated. Activities that must be considered for the Red River basin are:

- point source discharges and abstractions;
- irrigation demand and irrigation returns;
- municipal waste water discharges via infiltration ponds;
- operation of dams to regulate streamflows;
- diversions of water from one part of the basin to another; and,
- groundwater abstractions.

The HSPF model was selected to simulate the hydrology of the Red River basin for the following reasons:

1. Develop a good understanding of the hydrological conditions in the Red River basin. The mere act of setting up the model will force the investigators to develop an appreciation for the important influences on the hydrology of this basin.

2. Patch and extend the daily streamflow records available for the Red River basin. A total of seven USGS streamflow gauging stations have operated in the basin but only two are still active. In addition, some of the stations were operated on a seasonal basis or have missing periods of data. The simulated hydrographs from the HSPF model could be used to fill these missing data and to extend the records.

3. Provide simulated daily streamflow records at water quality monitoring points where no gauging station was operated. This is important so that constituent loadings can be computed at these locations.

4. The model allows for the water balance of the study area to be performed using a daily time step (as opposed to a monthly one). This is important with respect to computing accurate estimates of constituent loadings at the water quality monitoring points. Concentrations for many constituents can vary over wide ranges over short periods of time in the Red River and its tributaries. Accordingly, a more accurate estimate of chemical loading will be obtained using a daily time step than a coarser one. The use of a spreadsheet model would almost certainly limit the time step to a monthly increment. This would result in less accuracy in the computed loadings.

5. The model provides capability of "naturalizing" the USGS streamflow records. Land use in the Red River catchment has had a significant influence on the flows in the Red River over the past 100 years. Some of these influences are: groundwater and surface water abstractions for the Molycorp mill; diversion of water from the Molycorp Mine to the tailings impoundment via a pipeline; mine dewatering; operation of the tailings impoundment; groundwater abstractions for water supply to Town of Red River and Village of Questa; spring and surface abstractions for Fish Hatchery; point discharges from Red River waste water treatment plant and from Fish Hatchery; irrigation abstractions for about 3000 acres; abstractions of water for making artificial snow at a ski hill; and operation of the Cabresto Lake reservoir. All of these influences have had a variable influence on the observed flow records over the years. Few of the records could be considered to be homogenous (i.e., springing from the same population). For example, the flows in the Red River at the Ranger Station sometimes reflect a regime in which flows are being abstracted upstream for mill supply and sometimes not. The model could be used to simulate both historical conditions and natural conditions (i.e., no influence by human activities). The difference in these two simulations could be added back to the observed streamflow record at the Ranger Station to obtain a homogenous, "naturalized" flow record.

6. Provide easier data management than a spreadsheet. The Red River watershed is a complex system, requiring a large number of water balance components to be evaluated.

Furthermore, the Red River has been extensively studied and large databases of flow and water quality have been assembled. The structure of the HSPF model will make dealing with the complexity of the system and the large databases a much simpler task than would be the case with a spreadsheet.

7. Allows system to be simulated over a lengthy period of time. This is important because the water quality database for the Red River extends over a period of almost four decades (1965 to present). Ideally, the modelling of the system should extend over this entire period to maximize the use of the available data.

2.1.2 Water Quality Component

This component simulates the wash-off of constituents from pervious and impervious areas, and routes these constituents through river reaches and reservoirs. The model is capable of simulating a wide range of constituents. The ones of most relevance to the study at hand are conservative constituents and sediment. For the latter, the model has routines to simulate sediment detachment and transport. For the former, the model provides two approaches to simulate the constituent load washed from a basin:

- by association with sediment transport; or,
- as a function of water flow and the amount of constituent that has accumulated on the basin.

As for the hydrologic component, the water quality component must be calibrated for each constituent of interest. Adjustments are made to the model parameters until a satisfactory fit is obtained between simulated and observed constituent concentrations.

HSPF was selected to simulate the water quality regime of the Red River basin for the following reasons:

1. Similar to what was suggested above for the hydrologic component of HSPF, application of the model would force the investigators to develop a thorough understanding of the water quality regime of the Red River.

2. Patch constituent concentration records. Water quality samples in the Red River have generally been taken on a frequency of a month or less. This is inadequate to compute accurate load estimates for many constituents. The water quality regime of the Red River is erratic. Thunderstorms and rapid snowmelt cause large fluctuations in constituent concentrations over short periods of time. To improve the accuracy of the load estimates for the Red River, the HSPF model could be used to estimate the constituent concentrations during days when no grab samples were taken. This will be an improvement over merely using a single grab sample to represent the concentration of the Red River over an entire month, especially during periods of snowmelt and thunderstorms.

3. Provide potential means of simulating pre-mining conditions within the entire Red River basin. The hydrologic component of HSPF could be used to remove the effect of the mine

development on the Red River hydrology. The water quality component, in turn, could be used to simulate the natural constituent loadings derived from the area now occupied by the mine site. The basis for this water quality simulation will be the insights developed from the Background Characterization Study on the behaviour of scar-affected basins. Constituent loadings computed in the Red River above the mine development will also provide useful information on the loadings derived from hydrothermal scar areas.

4. Provide opportunity to investigate influence of antecedent flow conditions on water quality. Effects on water quality may exist at different time scales from a season to several decades. For example, concentrations in the Red River may potentially be greater following a dry period than a wet period, all other things being equal. This is because the dry period may allow for a "build-up" of constituent storage within the basin that would be subsequently washed into the Red River once the dry period broke.

5. Provides potential means of partitioning loads observed in Red River according to their sources. These sources can be categorized into three main groups: natural sources, the Molycorp mine, and other anthropogenic sources. The partitioning would be accomplished using successive model runs. For example, one run could represent the hydrology and water quality of the Red River without the Molycorp development. The difference between this run and the observed flows and water quality data of the Red River would represent the net effect of the mine development.

2.2 MODFLOW, MODPATH & MT3D

Groundwater flow and solute transport within the groundwater system is an important aspect in determining contaminant loads to the Red River. Groundwater flow models will be constructed as part of this comprehensive water and load balance study for two areas (c. Table 1):

- mine site;
- Red River alluvium (from mill site to Ranger Station).

We propose to use the numerical models MODFLOW, MODPATH and/or MT3D for these modeling exercises (Note that an alternative (finite-element) flow model may be required for the mine area if a discrete representation of fractures/faults and mine workings turns out to be critical). The proposed models are briefly described below.

2.2.1 MODFLOW

MODFLOW is a three-dimensional finite-difference model for groundwater flow developed by the USGS (McDonald and Harbaugh, 1988). MODFLOW is used to simulate systems for water supply, containment remediation and mine dewatering. The ability of the model to simulate a wide variety of systems, its extensive publicly available documentation, and its rigorous USGS peer review, have made MODFLOW the worldwide standard ground-water flow model. When properly applied, MODFLOW is the recognized standard model used by courts, regulatory agencies, universities, consultants and industry.

MODFLOW will be used in conjunction with the pre/post processor GMS, which is licensed to Robertson GeoConsultants Inc.

2.2.2 MODPATH

MODPATH is a particle tracking post-processing program designed to work with the USGS finite-difference flow model MODFLOW (Pollock, 1984). Output from steady-state or transient MODFLOW simulations is used in MODPATH to compute paths for "imaginary" particles of water (and solutes) moving through the simulated groundwater system. In addition, MODPATH keeps track of the travel time for particles through the system.

MODPATH will be used to define capture zones (e.g. for current dewatering of the underground mine) and critical paths of contaminant and the travel times along these paths. MODPATH will be used in conjunction with the pre/post processor GMS, which is licensed to Robertson GeoConsultants Inc.

2.2.3 MT3D

MT3D is a comprehensive three-dimensional numerical model for simulating solute transport in complex hydrogeologic settings. MT3D has a modular design that permits simulation of transport processes independently or jointly. MT3D uses a mixed Eulerian-Lagrangian approach to the solution of the three-dimensional advection-dispersion equation and is capable of modeling advection in complex steady-state and transient flow fields, anisotropic dispersion, first-order decay and production reactions, and linear and nonlinear sorption (Zheng, 1990).

MT3D is linked with the USGS groundwater flow simulator, MODFLOW. Once the groundwater flow model is calibrated, MT3D uses the calibrated (transient or steady-state) flow solution to simulate solute transport. In this way ground water flow and solute transport can be calibrated independently.

MT3D is widely used by universities, consultants and industry for simulating solute transport in groundwater and is accepted by courts and regulatory agencies throughout the U.S. and Canada.

MT3D will be used to simulate the transport of selected constituents in groundwater flowing within the Red River alluvium. MT3D will be used in conjunction with the pre/post processor GMS, which is licensed to Robertson GeoConsultants Inc.

2.3 META4

META4 is a reactive flow and transport model for river systems. META4 is part of the Water Analysis Simulation Program, WASP4 (Ambrose et al. 1993). The model was specifically designed to address metal problems in surface waters affected by natural and mining-related metal loadings. The most significant, recent modifications to the basic META4 model have been the addition of (i) a Double Layer Adsorption Model to represent the interactions of dissolved metals with the iron oxyhydroxides in the water column and the benthic region and (ii) variable pH simulation capability. These additions reduce the uncertainty in the ability of the model to reasonably represent future water quality for Zn, Cu, Cd and other sorbed metals as general major ion chemistry and metal transformation processes are varied. Algorithms for the simulation of crucial metal transformation processes, such as aqueous speciation, sorption/desorption, chemical precipitation/dissolution and kinetics are also included in META4. The current user manual for META4 (Version 3) describes the mathematical foundation for META4 and the details concerning the detailed application of the model, relevant data inputs, simulations options and other information (Martin and Medine, 1998).

The model has been applied to evaluate metal impacts and remediation for the Blackbird Mine Site (Idaho), Whitewood Creek (S. Dakota), Clear Creek (Colorado) and California Gulch (Colorado) for a variety of metals including Fe, Mn, Zn, Cd, Cu, As, Pb. At the Blackbird Mine Site, the model was used in two chemically different watersheds to evaluate the effectiveness of restoration options in meeting future water quality goals. The model evaluated a wide variety of control for both diffuse (groundwater) and point loads to the surface waters, including treatment, tailings consolidation, diversion and others. At the Whitewood Creek site, the model was used to evaluate catastrophic failure of a tailings impoundment and the resulting surface water impacts for arsenic, both particulate and dissolved. For the Clear Creek watershed, the modeling has been used repeatedly to evaluate diversion impacts, remediation of adit flows, sediment restoration, the need for and effects of metal treatment plants, and the optimum location for such facilities. Metals evaluated as part of the modeling included Mn, Fe, Al, Zn, Cu, and Cd. In Leadville at the California Gulch Site, the model has been used for many of the same activities (assessing remedial impacts for Zn, Cd), but was also used to assess contaminated soil runoff impacts from a large watershed tributary to California Gulch.

META4 will be used to simulate non-conservative (reactive) metal transport, transformations and fate in the Red River in the reach from the town of Red River down to the Ranger Station.

3 WORK PLAN

The following work plan outlines the scope of work for the load balance study covering the period February 2000 to December 2000. In general, this work plan follows the scope of work outlined in Molycorp's earlier submittal (May 1999). However, significant additions have been made to the scope of work including a study of the regional hydrology and a more detailed study of groundwater flow and transport (at the mine site and within the Red River alluvium). The task list originally provided (see Table 1 in Appendix A) has been modified to reflect these changes.

Task 1 Regional Hydrology Study

An important part of this work plan will be to draw up water balances for various areas within the Red River basin, including the mine site proper and the tailings impoundment. Each water balance will consist of a large number of flowlines, ranging from precipitation falling on a mine rock pile to abstractions from a well. All of the flowlines will have to be quantified. Where available, measured flows will be used for this purpose. However, in the majority of cases, the flowlines will be ungauged and some estimation technique will have to be employed. For flowlines related to hydrologic processes, such as precipitation and runoff, this will be done using a technique known as Regional Analysis. This entails examining the available climatic and hydrologic data in the region for general trends. The identified trends then form the basis for estimating ungauged flowlines. For example, mean annual precipitation (MAP) in a mountainous region typically increases with increasing elevation. Such a trend exists in the region of the Red River basin and will be exploited to estimate the MAP values at ungauged locations.

To develop the water balances, information will be required on three important hydrologic processes: (i) precipitation, (ii) evapotranspiration and (iii) runoff.

Task 1.1 Precipitation Analysis

A Regional Analysis will be performed to estimate the following precipitation characteristics at any ungauged location within the Red River basin:

- mean annual precipitation (MAP);
- average peak annual snowpack; and
- a series of annual precipitation values for the period 1965 to 1999.

Some work on the first characteristic has already been carried out. As mentioned above, MAP is observed to be empirically related to elevation in a mountainous region. To turn this observation into a quantitative tool, the networks of precipitation gages operated by the National Weather Service (NWS) and the Natural Resources Conservation Service (NRCS) were searched for data believed to be representative of the Red River basin. This search revealed a total of eleven stations in the region that could potentially be used to establish a relationship between MAP and elevation. Figure 1 shows the data from these stations plotted on a graph of MAP versus elevation. As can be seen, these data generally conform to the expected trend of increasing MAP with increasing elevation. All values of MAP used in this graph are representative of a common 30-year period (i.e., 1961 to 1990). This was done to eliminate one source of variation in the computed MAP values, namely the variation directly attributable to the existence of wet and dry cycles in the climate. By selecting a common averaging period, this source of variation is eliminated and all MAP values represent an identical mix of wet and dry periods.

An interpreted line was drawn on Figure 1 to approximate the conditions within the Red River basin. The line passes through the data points believed to be the three most representative (i.e., Cerro, Red River, and Red River Pass #2). These stations are located either within the basin or just outside its boundary. The interpreted line comprises two segments, a steep segment from 7000 feet to 8700 feet and then a mild segment for higher elevations. The interpreted relationship suggests a MAP value for the mine site of about 22 inches.

In undertaking the work plan, Figure 1 will be refined. This will largely involve incorporating additional data from the region. Snowpack characteristics will be estimated using the network of snow survey stations operated by the NRCS in the general vicinity of the Red River basin. The series of annual precipitation values will be assessed using the same database employed to derive the relationship between MAP and elevation

Task 1.2 Evapotranspiration Analysis

In this analysis both lake evaporation and evapotranspiration are of interest. The former refers to evaporation from a free-water surface while the latter refers to evaporation from a land surface, including transpiration from plants. Both rates will be estimated indirectly from meteorological data using a computer program known as WREVAP, which was developed by Environment Canada's National Hydrology Research Institute. The lake evaporation component of this program has been tested against the results of detailed water-budget estimates for 11 lakes in North America and Africa. The evapotranspiration component, on the other hand, has been tested against the long-term water-budget estimates of 143 experimental river basins in North America, Africa, Ireland, Australia and New Zealand. The meteorological inputs to the WREVAP model comprise humidity, temperature and sunshine duration (or global solar radiation). This model will be applied to those climate stations in the region where all three of the required climatic inputs are monitored. The resulting estimates of evaporation and evapotranspiration will be scrutinized for spatial and elevational trends. These identified trends will then form the basis for assessing the evaporation regime of the Red River basin. To check the estimates of lake evaporation, reference will be made to climate stations in the region equipped with Class A evaporation pans.

Task 1.3 Runoff Analysis

A Regional Analysis will be employed to estimate the following three runoff characteristics at ungauged locations within the Red River basin:

- mean annual runoff (MAR);

- average groundwater recharge; and,
- a series of annual average runoff values for the period 1965 to 1999.

Some preliminary work has already been carried out on the first characteristic. Based on the behaviour of precipitation examined in Figure 1, one would expect MAR to also exhibit a strong elevational trend within a mountainous region. To develop a specific relationship between MAR and elevation for the Red River basin, a search was made of the network of streamflow gauging stations operated by the USGS. This search revealed that a total of seven streamflow gauging stations have been operated in the Red River basin, six on the main stem and one on the largest tributary (Cabresto Creek). The periods of record for these stations are variable and only two of the stations continue to be operated.

Before being used in the runoff analysis, the raw data collected at the streamflow gauging stations were subjected to some processing. In essence, two manipulations of the data were required. Firstly, the average flow rate for each station was adjusted to be representative of the 30-year period from 1961 to 1990. Like the precipitation analysis above, this was done so that all the computed MAR values were representative of the same mix of wet and dry cycles in the climate. Secondly, a preliminary attempt was made to naturalize the MAR values (i.e., to remove the influence of human activity). For example, flows are diverted from Cabresto Creek for irrigation purposes at a point above the USGS gage on this stream. These diverted flows, which are also monitored by the USGS, were added back to the measured flows for Cabresto Creek to obtain a naturalized flow record.

Figure 2 shows the plot used to develop an empirical relationship between MAR and elevation. The vertical axis of this plot shows MAR expressed as an equivalent depth (i.e. the average annual runoff volume divided by the contributing drainage area). This is a convenient means of comparing the runoff from basins with vastly different drainage areas. The horizontal axis presents the "average basin elevation". This is the measurement adopted to represent the elevation characteristics of the basins controlled by the USGS gages. Two sets of data are plotted on Figure 2. One set represents the pair of MAR and "average basin elevation" values provided by each of the USGS stations. The second set is, in effect, a subset of the first set and represents pairs of data for incremental basins located between gages. For example, one of the data points represents the runoff and elevational characteristics of the incremental basin located above Station 2668.2 (Red River below Fish Hatchery) and below Stations 2650 (Red River near Questa) and 2660 (Cabresto Creek near Questa).

The data plotted on Figure 2 exhibit the expected trend of increasing MAR with increasing elevation. The shape of the empirical relationship is represented reasonably well by an exponential function. This relationship suggests that the MAR at the mine site is roughly 3 inches.

As part of this work plan, Figure 2 will be refined. This will primarily involve continuing the process of naturalizing the USGS streamflow records. Also, the MAR analysis will be checked using a climatic water balance based on the precipitation and evaporation analyses outlined above. A climatic water balance is applied by subtracting mean annual evapotranspiration from mean annual precipitation. The result is an estimate of MAR, expressed as an equivalent depth. The estimation of the other two runoff characteristics of interest (i.e., groundwater recharge and the annual series of runoff values) will be performed using the same streamflow records as used for the MAR analysis.

Task 2 Load Model for Background Watersheds

A comprehensive investigation is planned for the coming field season to examine the hydrology and water quality regime of the scar-affected basins within the Red River watershed but outside the boundaries of the mine area (see Work Plan for Background Study submitted under separate cover). This investigation calls for the collection of numerous spot flow measurements and water quality grab samples at key locations within the three selected study basins (i.e. Hanson, Straight, and Hottentot Creeks). Although an intense monitoring program is proposed for these basins, the number of samples required to build up a complete picture of the water quality regime of the basins would be prohibitive. Instead some modeling technique will be required to estimate monthly and annual loads from these watersheds. It would be possible to fill the gaps by a relatively simple technique for streams of fairly constant discharge and chemical concentration. However, in streams with erratic flow and water quality regimes, such as Hanson, Straight and Hottentot Creeks, this technique is inadequate and a conceptual-type model that simulates the movement of water and chemical loads is needed. As outlined in Section 2, HSPF is such a model. The sections below describe how this model will be used to construct the water and load balances for at least one of the background basins, the most likely candidate being Straight Creek.

Task 2.1 Data Review

Data are required for the purposes of providing input to the HSPF model and verifying the model outputs against actual data. The data can be categorized into two types, namely hydrometeorological (e.g., precipitation data) and geometric (e.g., drainage area). For the Background Characterization Study, the most important data are listed below:

- precipitation, air temperature, dewpoint temperature, wind, and solar radiation (all at hourly increments);
- average monthly potential evapotranspiration;
- frequent spot measurements of flow;
- frequent grab samples of water quality data;
- drainage areas; and,
- channel characteristics.

The meteorological data will be obtained from a total of three automated weather stations, two operated within the Straight Creek basin and the other on a mine rock pile in the mine area. Estimates of evapotranspiration will be made using the WREVAP model described in Task 1.2.

The remainder of the required input and verification data will be collected during the field season.

Task 2.2 Conceptualization of Flow and Transport

The first step in setting up the model will be to conceptualize the study basin as a group of land segments connected by a network of stream reaches. A two step process will be undertaken to define the boundaries of the land segments. Firstly, the study basin will be subdivided into two or three subbasins, as dictated by the locations of flow and water quality monitoring stations. This subdivision is important so that the output from the HSPF model can be checked at intermediate points in the study basin where observed data are available. The second process involves dividing each subbasin into smaller land segments that have reasonably homogeneous geochemical and elevational characteristics. A similarity in geochemistry is desirable because the scar-affected areas, fan deposits, and non-scar areas exhibit widely different chemical and erosional behaviour. HSPF will likely have more success in simulating the water quality from the background basins if these various areas can be modelled independently, rather than being lumped together. Selecting land segments with small elevation ranges is advantageous for the modelling of the snowmelt processes: snowpack development, snowpack ablation, and migration of the snowline, all of which strongly depend on elevation. For the purpose of improving the simulation of snowmelt, the land segments will be made to conform to elevation bands with intervals no greater than 800 ft.

The stream channel of each study basin will be configured as two parallel networks of stream reaches, one to represent surface flow within the channel and the other to represent the groundwater flow in the stream alluvium and in the fan deposit. Allowance will be made for communication between the "surface flow" reaches and the "groundwater flow" reaches. HSPF uses a "storage routing" method to simulate the movement of water through a channel. To implement this method, HSPF requires outflow from the channel to be specified as a function of either channel volume or depth. For the "surface water" reaches, Manning's equation will be used to establish the relationship between discharge and depth. Darcy's equation, on the other hand, will be employed to characterize the hydraulics of the "groundwater flow" reaches. A set of parallel reaches is desirable to simulate the ephemeral nature of the lower reaches of the study basins, particularly in the region of the fan deposits.

The study basins are small and, therefore, will tend to exhibit wide fluctuations in flow over short periods of time, due both to diurnal variations in snowmelt and to short duration rainfall events. To capture this erratic behaviour with the model, HSPF will be operated on a short time step of about 1 hour to 3 hours. This short time increment can be supported because the input meteorological data will be measured at 1 hour increments. The period of simulation will be approximately from April 2000 to October 2000, i.e. the scheduled period of intense monitoring within the study basins.

Task 2.3 Setup of HSPF Model

Inputs to the model comprise calibration parameters, geometric data, hydrometeorological data and initial conditions. The snow survey conducted in the early spring of 2000 will be used to characterize the snowpack at the beginning of the simulation period. Setup of the model will entail creating the required input files and entering the hydrometeorological data into the file management system (known as WDM files).

A "first cut" at the calibration parameters will be based on the experience gained in applying the HSPF model to the entire Red River basin (see Task 6 below).

Task 2.4 Calibration of Flow Model

The calibration parameters controlling runoff generation will be adjusted until satisfactory agreement is reached between the modelled streamflow record and the frequent spot flow measurements. Comparisons between modelled and observed flows will occur at a minimum of two locations (approximately midway along the main stem and near the mouth).

Plots of modelled and observed flows will be created to demonstrate the goodness of fit obtained. Also, a flowsheet will be prepared that illustrates the hydrological processes acting in the selected background basin. Figure 3 shows an example of a tentative flowsheet drawn up for the Hansen Creek basin. Boxes represent either subbasin surfaces or groundwater aquifers. Lines represent the various components of the hydrologic cycle acting on the subbasins or within the aquifers. The collected meteorological data and results from the HSPF model will be used to quantify the magnitude of these lines.

Task 2.5 Calibration of Conservative Load Model

HSPF contains a set of process algorithms for simulating the washoff of conservative constituents from pervious areas and then routing these constituents through a network of stream reaches. These algorithms will be employed to simulate the generation and transport of sulfate through the selected background basin.

The calibration of the water quality component of HSPF will only occur once a satisfactory calibration with flow is achieved. In the water quality calibration stage, the main objectives will be to minimize differences between observed and modelled average sulfate loads and sulfate concentrations. It will be necessary to maintain a reasonable balance between initial and final storages of available sulfate within the background basin to ensure that the simulated loads are representative of a stable regime.

The results of the sulfate modelling will be graphically illustrated on a flow sheet similar to Figure 3.

One of the objectives of applying the HSPF model to Straight Creek, or to another one of the background study basins, is to develop a model representation of the generation and transport of sulfate from scar-affected areas. This model will comprise a mathematical expression that simulates both the accumulation of available sulphate load and the subsequent transport of this sulfate from the land surface into the stream. The parameters for this mathematical expression will be estimated during calibration of the HSPF model. No two scar areas can be expected to act in an identical manner and, therefore, the calibration parameters derived for Straight Creek can not be used as a universal guide to the behaviour of hydrothermal scars throughout the Red River basin. These calibration parameters will require some adjustment to make them representative of the varied geochemical characteristics of the different scar areas. This will be done in an empirical way by combining the results obtained in this task with the findings from the Background Characterization Study (see Work Plan for Background Study submitted under separate cover). As described in the work plan for the background study, the prominent scar areas in the Red River basin will be ranked according to their geochemistry. Each scar area will be assigned a number from 1 to 5 indicating their degree of ARD production. For example, assuming the background study reveals that sulfide content and erodibility were the main factors in sulfate loading the scar areas may be ranked as follows:

1. high sulfide content and rapid erosion;
2. high sulfide content with moderate erosion or moderate sulfide with high erosion;
3. moderate sulfide content and moderate erosion;
4. low sulfide content content and moderate erosion or moderate sulfide content with low erosion;
5. low sulfide content and low erosion.

Empirical relationships will be developed to relate these rankings to the calibration parameters derived for Straight Creek. This empirical relationship will, in turn, be used to assign calibration parameters for the scar areas elsewhere in the Red River basin.

Task 2.6 Calibration of Reactive Load Model

After using the model to simulate sulfate, an attempt will be made to simulate various reactive constituents. Provided that the given constituent exhibits some flow dependency (e.g., higher concentrations with higher flow), the model may be able to reproduce, fairly well, the behaviour of the reactive constituent. In effect, the model parameters derived through calibration would implicitly account for the non-conservative behaviour of the constituent.

The geochemical controls which ultimately result in the (empirical) relationships of flow and concentrations that were developed by model calibration will be investigated using geochemical modeling (using either PHREEQC or MINTEQA2). An understanding of the geochemical controls on reactive solute transport will assist in using the HPSF model results for predictive modeling (i.e. for periods other than the calibration period).

Task 3 Load Model for Mine Area

Development of the mine area has had an influence on both the hydrology and the water quality regime of the Red River. This influence has been variable over the years, depending on two main factors: the stage of the mine development; and, the remediation measures that were in place at the time. The coupled effect of these factors has been to progressively reduce the amount of water that enters the middle reach of the Red River from the mine site. The specific actions that have had the most impact are:

- progressive change of the Sulphur Gulch drainage pattern by developing the open pit;
- connection of the open pit and the old underground mine via adits and shafts that were daylighted during development of the open pit;
- connection of the new and old underground mine workings by a borehole;
- capture and diversion of drainage from upper Capulin Canyon to Goathill Gulch;
- creation of the caved zone, which effectively diverted surface and groundwater flows from Goathill Gulch to the underground mine workings;
- diversion of mine dewatering flows to the tailings impoundment via the tailings slurry pipeline;
- creation of a groundwater capture zone by development of the underground and surface mine workings and by dewatering these mine workings; and
- implementation of a stormwater management system.

In addition to reducing runoff from the mine site, the mine has also altered the flow of the Red River by making abstractions for the mill water supply. Abstractions have been obtained both directly from the river and from wells developed in the river alluvium.

To assist in understanding the influence of the mine site on the Red River, water and chemical load balances will be drawn up for the mine site proper. In recognition of the variable effect this mine has had over the years, the water and chemical load balance will be reconstructed for the period 1965 to 1999, thus spanning the complete period of pit development and the subsequent period of mining in the new underground workings. The historical water and chemical load balances will serve three purposes, namely to:

- document how the mine development has altered the local drainage patterns over the years from 1965 to 1999;
- provide a means of reconciling all of the measured flowlines within the mine development; and,
- provide a basis from which to represent the mine operation within the HSPF model.

Task 3.1 Data Review

Four general types of information will be required to reconstruct the historical water and chemical load balances:

- history of mine development, including mine production, schedule of pit development, and schedule of placement of mine rock piles;
- history of remediation measures;
- observed records of flow and water quality for such flowlines as river abstractions, mine dewatering and liquid fraction of tailings slurry;
- observed records of storage and water quality within the underground mine workings during temporary shutdowns.

This information will be obtained from a variety of sources:

- reports prepared by Molycorp and its consultants;
- reports prepared by the regulatory agencies (e.g., NMED and the USEPA);
- filing systems of Molycorp and some of its consultants, particularly Vail Engineering Inc.; and,
- interviews with mine personnel.

A considerable number of reports prepared by the regulatory agencies and Molycorp's consultants have already been reviewed to assist in preparing this work plan.

Task 3.2 Development of Mine Water Balance

Development of the water balance will essentially involve two broad steps:

- conceptualize the mine site as a system of interlinked components; and,
- quantify the amount of flow generated by the components and the amount of flow passed between the components.

Figure 4 graphically illustrates a preliminary effort at performing the first step. Boxes on the figure depict components while lines represent the movement of water between the components. In effect, this figure illustrates our understanding of the system, as gained while reviewing the available documents on this project. A total of eight components have tentatively been chosen to represent the mine site. Six of the components are related to basins while the remaining two represent the old and new underground mine workings. Figure 5 is a topographical map showing the boundaries of the six selected basins.

Figure 4 can be thought of as representing an overall picture of the mine site water balance, as it exists today. To develop a thorough understanding of the generation, movement and storage of water within the mine area, some of the basins will have to be examined in greater detail than is implied in Figure 4. One of these basins is Capulin Canyon, which contains two seepage collection barriers, a pumping system, and a diversion to Goathill Gulch. Figure 6 shows a tentative representation of the Capulin Canyon system that will be used in the water balance analysis. Similar detailed representations will be developed for the basins of Goathill Gulch, Sulphur Gulch and the mill area.

The second step in the water balance analysis will entail estimating the magnitude of the various flowlines. Several approaches will be called upon to do this. Climatic flowlines (evapotranspiration and precipitation) and hydrologic flowlines (runoff) will be estimated using the Regional Hydrology Study outlined above in Task 1. Groundwater flows and infiltration will be assessed using the results from the groundwater study outlined below in Task 3.3. Abstractions, diverted flows and underground mine storage will be quantified, as much as possible, with measured values. Finally, the continuity equation (i.e., $I - O = \Delta S$) will be relied upon to estimate flowlines that can not be assessed using the other techniques listed above.

The historical water balance will be programmed on an Excel spreadsheet and, as mentioned above, will span the period from 1965 to 1999. The spreadsheet will incorporate the following features:

- an annual time step;
- allowance will be made for the progressive changes to the local drainage patterns as the mine was developed (e.g., runoff from the upper Goathill Gulch originally flowed to the Red River, but with the creation of the caved area, it was subsequently diverted to the underground);
- allowance will be made for the different runoff characteristics of mine rock piles and the natural areas which they overlie; and,
- flowsheets (like Figures 4 and 6) will be created in the spreadsheet for presentation of the spreadsheet output and to allow for automatic updating of the flow magnitudes associated with each flowline.

Task 3.3 Groundwater Flow Model

Groundwater flow is a major component of the mine water balance. This is illustrated by the absence of any significant surface runoff (other than from Capulin mine rock pile, which is intercepted and redirected into the underground workings). At the same time, the hydrogeology of the mine area has been significantly altered due to the development of the underground workings, open pit and cave zone. At present, the underground workings are being dewatered which has resulted in a cone of depression that captures much of the groundwater flow within the mine area. A groundwater flow model will be developed for the mine site to better understand the impact of mine development and dewatering on local groundwater flow and to assess the current and future potential for off-site migration via groundwater.

Initially, a conceptual model of groundwater flow in the mine area will be developed based on a review of historic records of exploration logs, inflows to the mine during mine development, and results of recent groundwater investigations (since 1994) and pumping records. Based on this review a suitable numerical model will be selected (either a finite-difference model such as MODFLOW or a finite-element model such as FEFLOW or FEMWATER depending on the complexity of the system) and a numerical groundwater flow model constructed. The groundwater flow model will be calibrated against observed inflows to the underground workings and groundwater levels observed in the various monitoring wells installed since 1994.

Particle tracking (e.g. MODPATH) will be used to simulate the trajectories (pathways) of potentially contaminated seepage, which may enter the groundwater system at the base of the various mine rock piles. Using this technique the areal extent of the mine rock piles lying within the capture zone of the current dewatering of the underground workings will be estimated. Travel times will be estimated for those trajectories that fall outside the capture zone and have the potential to reach the Red River.

The calibrated groundwater flow model will also be used to assess the effect of alternative closure measures on groundwater flow and ultimately contaminant transport via groundwater to the Red River. The results of the groundwater flow modeling will be incorporated into the mine water balance (Task 3.2) as well as the conservative and reactive load models for the mine site (Tasks 3.4 and 3.5).

Task 3.4 Development of Conservative Load Model

The spreadsheet model outlined in Task 3.2 will be expanded to include a water quality component. Being a mass balance model, this water quality component will be restricted to dealing with conservative constituents (i.e., constituents that are not subject to significant attenuation by physical, chemical or biological processes). Sulfate or total dissolved solids are potential candidates for this purpose.

The water quality model will be used to reconstruct the constituent annual load balance for the period 1965 to 1999 (or for whatever period the data allows). The water quality database for the mine area is not as extensive as the flow database and, accordingly, estimates will have to be made for missing data. The reconstructed load balance will serve three purposes. Firstly, it will allow identification of the main sources of loading within the mine area for the selected constituent. Secondly, it may allow an assessment of how loadings within the confines of the mine development have changed through the years. Thirdly, the load balance may enable the identification of inherent problems in the flow data, which would not necessarily be evident if the water balance was prepared in isolation. For example, if the load balance reveals significant imbalances, such as unexplained sinks or sources, the flow magnitude of one or more of the flowlines may have to be adjusted to eliminate the imbalance.

Flow sheets like Figures 4 and 6 will be used to present the results of the load balance calculations in a graphical format.

Task 3.5 Development of Reactive Load Model

A reactive load model will also be developed for those non-conservative constituents that may be of concern to the Red River system (e.g. Al, Fe, Mn, Zn, Cu, Cd). The reactive load model will be similar to the conservative load model (spreadsheet model with annual time steps) and will be based on concentrations of these constituents obtained from laboratory leach extraction analyses of representative samples of the various sources (e.g. scar material, mineralized mine rock, open pit wall). The leach extraction results may be used directly (say in case of surface runoff from scar areas) or may have to be corrected for field moisture content (e.g. in case of pore water concentrations in the mine rock dumps). Geochemical modeling using software such as MINTEQA2/PRODEFA2 is envisioned in order to account for geochemical controls known to be present in surface flow or pore water (e.g. dissolution/precipitation of secondary minerals such as gibbsite and gypsum).

The calculated concentrations will be reconciled with observed water quality data from nearby seeps, streams and/or groundwater monitoring wells, where available. The importance of geochemical reactions along a flow path (e.g. buffering in the bedrock aquifer) will be evaluated by comparing observed water quality along a flow path. If deemed critical for estimating chemical loads to the Red River, geochemical reactions along the (groundwater) flow path will be modeled using reactive transport modeling software such as PHREEQC.

The resulting 'source' concentrations will be used to develop a load estimate for non-conservative constituents to the Red River that will be incorporated into the water/load balance spreadsheet.

Task 4 Load Model for Tailings Area

The tailings impoundment was commissioned in 1965 at a location about 8 miles west of the mine area. Important features of this facility are:

- it comprises two tailings storage areas (created by the construction of Dam No. 1 and Dam No. 4);
- diversion ditches were constructed around the facility to minimize inflows to the storage areas;
- a groundwater interception system was constructed (including seepage barriers and extraction wells) below the tailings facility to intercept contaminated seepage and to pipe it to the Red River (Outfall 002);
- the facility has a large storage capacity that acts to regulate the inflow of runoff and tailings slurry water;
- the facility causes a net increase in evaporation from the Red River basin due to the ponding of water; and,
- decant water (if present) is processed by a water treatment plant before being released to the Red River.

Historical water and chemical load balances will be constructed to develop an understanding of how the tailings impoundment influences the hydrology and water quality of the Red River. These balances will cover the period from 1965 to 1999, thus spanning the full period since the facility was commissioned.

Task 4.1 Data Review

Four general types of information will be required to reconstruct the historical water and chemical load balances:

- history of dam development for the tailings impoundment;
- history of remediation and water management measures;
- observed records of flow and water quality for such flowlines as Outfall 002 and the influent flows to the water treatment plant; and,
- estimates of volumes of water contained in tailings voids and the ponds overlying deposited tailings.

This information will be obtained from a variety of sources:

- reports prepared by Molycorp and its consultants;
- reports prepared by the regulatory agencies (e.g., NMED and the USEPA);
- filing systems of Molycorp and some of its consultants, particularly Vail Engineering Inc.; and,

- interviews with mine personnel.

Task 4.2 Development of Tailings Water Balance

The development of the tailings water balance will be done in much the same way as described for Task 3.2. In summary, the following steps will be undertaken:

- the tailings impoundment will be conceptualized as a system of components; and,
- the magnitudes of the inflows, outflows and storages for each component will be estimated.

This work will be facilitated by setting up the historical water balance on an Excel spreadsheet. As for the mine site, the water balance will be constructed using an annual time step. A flowsheet similar to Figure 3 will be developed to graphically illustrate the generation, storage, and movement of water within the boundary of the tailings facility.

Task 4.3 Review and Update of Groundwater Flow Model

All groundwater data for the tailings area (groundwater quality, static water levels, and seepage volumes collected by the interception system) reported since submission of the most recent groundwater flow model for the tailings area (October 1997) will be reviewed. If the new groundwater data differ substantially from those used for initial model calibration, or if water balance calculations (Task 4.2) indicate that the existing model may be inaccurate, then the existing groundwater flow model will be revised to reflect changes in current groundwater conditions.

The results of the groundwater flow model will be incorporated into the detailed water balance for the tailings area (Task 4.2).

Task 4.4 Development of Conservative Load Model

The spreadsheet developed in Task 4.2 will be expanded to include the capability of computing chemical loads. The spreadsheet will be used to examine the loadings for a conservative constituent such as sulfate. The reasons for undertaking this task are identical to those outlined above for performing Task 3.4.

Task 4.5 Development of Reactive Load Model

A reactive load model will be developed for those non-conservative constituents that may be of concern to the Red River system (e.g. Al, Fe, Mn, Zn, Cu, Cd). This spreadsheet model will be based on concentrations of these constituents obtained from laboratory leach extraction analyses of representative samples of the tailings corrected for field moisture content (see Appendix C of RGC Report 052004/1 for an example of this approach). Geochemical modeling using software such as MINTEQA2/PRODEFA2 is envisioned in order to account for geochemical controls known to be present in pore water (e.g. dissolution/precipitation of secondary minerals such as gibbsite and gypsum).

The calculated concentrations will be reconciled with observed water quality data from nearby seeps and/or groundwater monitoring wells, where available. The importance of geochemical reactions along a flow path (e.g. buffering in the alluvial aquifer) will be evaluated by comparing observed water quality along a flow path. If deemed critical for estimating chemical loads to the Red River, geochemical reactions along the (groundwater) flow path will be modeled using a reactive transport modeling software such as PHREEQC.

The resulting 'source' concentrations will be used to develop a load estimate for non-conservative constituents to the Red River that will be incorporated into the water/load balance spreadsheet.

Task 5 Groundwater Flow & Transport Model for Red River Alluvium

During much of the year most, if not all, ARD from mineralized sources upstream and within the mine area reaches the Red River system via groundwater flow. This subsurface contribution does not enter the Red River directly (except for perhaps some isolated springs at the Red River) but instead mixes first with the groundwater (underflow) in the Red River alluvium (see discussion in Work Plan for Background Study submitted under separate cover). The physical and geochemical processes resulting in mixing of the ARD impacted groundwater and the well-buffered groundwater flowing within the alluvial aquifer of the Red River valley will be simulated as outlined below.

Task 5.1 Data Review

The following data will be compiled and reviewed:

- borehole logs of all groundwater wells completed in the Red River alluvium and underlying bedrock (in the reach from Red River to Ranger Station);
- water levels and water quality in all monitoring wells completed in the Red River alluvium and underlying bedrock (in the reach from Red River to Ranger Station);
- records of pumping (for mill water supply) and pump test data for wells in the Red River alluvium;
- field surveys and studies of accretion (recharge by groundwater) to the Red River.

Based on this review a conceptual model will be developed of groundwater flow in the Red River alluvium (also referred to as "underflow") and of the chemical reactions controlling groundwater quality.

Task 5.2 Well Installation and Monitoring

A preliminary review of the data suggests that (i) groundwater flow in the Red River alluvium entering the mine reach (at the mill site) is much greater than downstream of the mine (e.g. at the Ranger Station); and (ii) the water quality of the groundwater flowing in the north side of the Red River alluvium is much poorer (due to contributions of ARD impacted groundwater from the northern, scar-impacted area) compared to groundwater flowing in the south side of the alluvial aquifer. Additional monitoring wells will be installed in the Red River alluvium to test these hypotheses (assuming access is granted by the U.S. Forest Service).

Prior to drilling, an attempt will be made to determine the depth to bedrock across the Red River valley using geophysical methods (seismic survey). A trial run will be completed in vicinity of existing wells where the geophysical test results can be verified against observed depth to bedrock (from drilling). If deemed successful geophysical surveys will be run across the Red River valley at selected locations to determine the bedrock profile and cross-sectional area of the alluvial aquifer.

Figure 7 shows preliminary locations for the proposed monitoring wells in the Red River alluvium. Three sets of "well fences" will be drilled perpendicular to the Red River in proximity of the sampling stations #7, #12 and #16 to assess the expected variability of groundwater flow and quality in the Red River alluvium. These drill locations will be finalized after review of the results of the seismic surveys, the data review (Task 5.1) and a site reconnaissance (to determine access for a drill rig).

The three centre wells will be completed as pumping wells (using large diameter casing of at least 12") while the adjacent wells (towards the sides of the valley) will be completed as monitoring wells (2" diameter). Consideration is being given to installing 2-3 additional mini-piezometers per monitoring well to allow water quality sampling at various depths. These mini-piezometers would consist of 1/4" polyethylene tubing leading from the sampling point to surface, with the end perforated and wrapped in filtercloth (for sampling). The string of 2-3 mini-piezometers would be tied either directly to the outside of the 2" PVC casing or to an additional (smaller) PVC rod which would be lowered down the same borehole as the 2" PVC casing. The mini-piezometers would be sampled by applying suction to the tubing at surface.

The installation of the monitoring wells will be supervised by a qualified geologist and/or hydrogeologist. First, the borehole will be drilled to bedrock to determine the total depth of the aquifer. During drilling the water quality of the return water will be monitored for field parameters (pH and EC). Where a significant change in water quality is observed drilling will be interrupted and a water quality sample taken (to the extent practical) for more detailed laboratory analysis. If used, the bundle of mini-piezometers would then be inserted into the borehole and the casing pulled back to about 35ft below the water table (allowing caving of the borehole) and completed with a 40 ft screen and riser pipe. All monitoring wells will be completed using appropriate filter pack material, bentonite seals and cement-grouting of the annulus to surface and will be developed (purged) prior to initial sampling.

A constant-rate pump test will be performed at each centre well (anticipated pumping rates in the order of 1000-2000GPM over a period of 3-4 days) using the appropriate neighbouring wells as observations wells. Based on this pump test the transmissivity of the alluvial aquifer at the three locations will be estimated.

The new monitoring wells (and mini-piezometers, if installed) will be sampled for water quality on a quarterly basis. The water quality parameters to be measured include relevant field parameters (pH, electrical conductivity, and temperature), all major anions and cations, and the metals of interest (Al, Fe, Mn, Cd, Co, Cu, Ni and Zn). Samples for metals analysis will be preserved with HNO_3 to pH <2. Samples for anions will be transported to the lab on ice and kept under refrigeration until analysed. Equipment blanks and field replicates (~5% of all samples) will be collected to check for contamination and reproducibility. Sample containers will be sealed in the field and chain-of-custody procedures will be employed for all samples.

The new wells in the Red River alluvium will be sampled at the same time as the existing monitoring wells (to the extent practical) for the period of one year to determine seasonal variations in groundwater quality. The static water levels in the various wells (and other existing wells in the Red River alluvium) will be read at least once a month (likely more often during peak runoff) for the period of one year.

Task 5.3 Setup of GW Flow & Transport Model

A groundwater flow and transport model will be developed for the Red River alluvium with the objective to synthesize all available hydrogeological information in a consistent and coherent model. Groundwater flow in the alluvial aquifer will be simulated using the well-documented USGS finite-difference code MODFLOW. The model domain will encompass the Red River reach from the upper fence of wells (just upstream of the mill site) to the lower fence of wells (near the Ranger Station). The information gained from drilling, testing and water level monitoring of the upper and lower fence of wells will provide defensible upstream and downstream boundary conditions. Additional groundwater inflow from the side slopes will be simulated using flux boundaries. The Red River will be included explicitly in the model using the STREAM package which allows groundwater recharge (from the stream to the aquifer) or groundwater discharge (from the aquifer to the stream) depending on the groundwater elevation relative to the stream stage.

The transport of selected conservative solutes (e.g. EC, sulfate) in groundwater will be simulated using the 3D transport model MT3D. MT3D uses a mixed Eulerian-Lagrangian approach to simulate advection and dispersion of a solute within the flow field computed with MODFLOW. The geochemical controls (complexation, precipitation/dissolution, adsorption) during the transport of reactive constituents (e.g. Al, Cu, Zn) in the alluvial aquifer will be evaluated using PHREEQC (V. 2) or a similar reactive transport model. PHREEQC is ideally suited for modeling chemical reactions due to mixing (of groundwaters with differing composition) or interaction with solids (adsorption etc.) occurring along a groundwater flow path.

Task 5.4 Calibration of GW Flow & Transport Model

The groundwater flow model will be calibrated against groundwater levels and changes in Red River flows (due to interaction with the alluvial aquifer) observed during low flow periods. In addition, observed changes in groundwater levels as a result of pump testing and (variable) pumping for mill water supply may provide additional (transient) calibration targets.

The conservative transport model will be calibrated using the observed water quality (EC, sulphate) in the various monitoring wells completed in the alluvial aquifer. The calibration of the transport model will provide an independent check on the calibrated groundwater flow solution. The results of reactive transport modeling (i.e. identification of key geochemical controls) will be assessed qualitatively by comparing predicted and observed concentrations of reactive contaminants.

The results of the groundwater flow and transport modeling will be incorporated into the conservative load model (HPSF) and reactive load model (META4) for the Red River basin. It is anticipated that the specific results of the groundwater flow and transport model (calibrated for low flow periods) can be generalized to be applicable for the longer modeling period (i.e. for high flow periods and beyond the calibration period) covered with the conservative load model.

Task 6 Conservative Load Model for Red River Basin

The development of an overall water and load balance model for the Red River basin will be required to:

- quantify constituent loadings at key locations within the basin;
- assist in apportioning these loadings according to the various sources within the basin (i.e., mine development, hydrothermal scars, other natural sources and other anthropogenic sources); and
- simulate the effects of various proposed closure measures on the water quality of Red River.

Two different approaches were considered for developing this model, namely a spreadsheet mass balance and a conceptual-type hydrologic model (known as HSPF). The latter approach was selected, largely on the strength of two considerations. Firstly, the concentrations of many constituents in the Red River fluctuate widely over short periods following thunderstorms and periods of rapid snowmelt. This condition can best be represented in a model using a short time step of hours to days. The HSPF model can easily handle such short increments, but a spreadsheet model of the system would be most unwieldy at these increments. Spreadsheet models are normally operated on time steps no shorter than a month, especially when a lengthy simulation period is being considered, as is the case for the Red River basin study (i.e., 1960 to 2000).

The second consideration in adopting the HSPF model was the voluminous amount of data that would have to be handled during the modelling exercise. The Red River has been extensively studied and, as a result, large databases of flows and water quality have been amassed over a lengthy period of time. Furthermore, the modelling exercise must account for the progressively changing land use that has taken place within the Red River basin over the years. A significant amount of data will be required to quantify these changes. Overall, the modelling exercise will entail considerable data handling and processing. The HSPF model is better suited for this purpose than a spreadsheet mass balance.

Task 6.1 Data Review

Data are required for the purpose of providing inputs to the HSPF model and for verifying the model outputs against observed data. The most important types of data are:

- precipitation and air temperature (both on a daily increment);
- dewpoint temperature, wind, and solar radiation (all on a daily increment);
- snow water equivalent of snowpack (usually monitored twice monthly during winter and spring);
- estimates of monthly average potential evapotranspiration;
- monthly abstractions (e.g., pumping from Columbine wells);

- monthly point source discharges and associated water quality (e.g., treated effluent from Town of Red River);
- irrigation demand and irrigation returns;
- records of water quality grab samples at various locations within the Red River basin;
- drainage areas;
- characteristics of dams, including dates of construction and raising (both Cabresto Lake and tailings impoundments);
- characteristics of stream channels; and,
- daily records of streamflow.

The meteorological data listed above will be obtained from the network of climate and snow course stations operated by the NWS and the NRCS. Data on precipitation, temperature, and snow pack will be obtained from several long-term stations within and just bordering the Red River basin (e.g., Cerro and Red River). For the other meteorological data, reference will have to be made to stations further afield (e.g., Albuquerque and Alamosa). Estimates of evapotranspiration will be made using the WREVAP model (see Task 1.2).

Data will be required on land use activities in the Red River basin not related to the Molycorp Mine. These will be obtained from a variety of sources, including a series of water-use publications prepared by the USGS. The municipalities and irrigation districts within the Red River basin may have to be contacted directly to obtain some of the necessary information. The USGS monitors some of the flows diverted for irrigation purposes within the Red River basin.

The daily streamflow data required for verifying the model output will be obtained from six USGS streamflow gauging stations that have operated in the basin over the period of interest (i.e., 1960 to 2000).

The water quality data required for model verification will be obtained from the extensive database available for the Red River basin. These data have been collected by NMED, USGS, U.S. Bureau of Land Management, USEPA, U.S. Forest Service, Molycorp, and Molycorp's consultants. (The assembly of these data into a single database is covered under a separate work plan.) Only a fraction of the water quality monitoring points coincide with one of the USGS streamflow gauging stations.

The U.S. Bureau of Land Management conducted a detailed assessment of physical habitat for fish in the lower reach of the Red River. As part of this assessment, a longitudinal profile and many cross sections of the Red River were surveyed. These data will be obtained and used to characterize the geometry of the lower reach of the Red River. The survey will also be used to establish "between-station" hydraulic geometry relationships that can be used to estimate the geometry of the Red River in its upper reaches. Supplemental information will be obtained from cross-sectional surveys that will be conducted this year in the reach of the river next to the mine area.

Task 6.2 Conceptualization of Flow & Transport

The Red River basin will be subdivided into at least ten subbasins, as dictated by the locations of streamflow gauging stations, water quality monitoring stations, tributary confluences, the mine area, and the tailings impoundment area. Each of these ten subbasins will be further subdivided into land segments, according to two criteria: elevation and geochemistry. Land segments will be made to conform to elevational bands so that the model can better simulate the snowmelt processes in this mountainous area. The land segments will also be defined by boundaries between scar areas and non-scar areas to allow independent simulation within the model of the vastly different chemical behaviours of these areas.

A network of stream reaches will be developed to tie all the land segments together. In the reach of the Red River running from the Town of Red River to the Questa Ranger Station, a parallel set of stream reaches will be specified. One set will be used to simulate the movement of water in the Red River channel, while the other will be employed to represent the flow of water in the alluvial fill. Allowance will be made for interchanges between these two sets of stream reaches.

The modelling studies outlined in Tasks 2 through 5 will provide the basis for the HSPF representations of the background study basins, the mine area, the tailings impoundment area, and the reach of Red River adjacent to the mine area. The representations of the mine area and the tailings impoundment area will reflect the historical activities that have occurred on these two sites. For example, allowance will be made for the changes in drainage patterns caused by the initial construction and subsequent raising of the various dams used to form the tailings impoundment. As another example, the model will simulate the varying levels of abstractions made by the mill from the Red River over the period of simulation.

HSPF will also examine the influences of land-use changes related to irrigation and urbanization. For example, allowance will be made for changes in the effluent discharged from the Town of Red River's sewage treatment plant over the years. Also, an accounting will be made for variations in the amount of water abstracted for irrigation purposes from year to year.

The drainage area for the Red River is large and, accordingly, a daily time step should be adequate for simulating the water quality fluctuations in this river. In any event, the available hydrometeorological data (e.g., precipitation and streamflow) are only available on a daily time increment and, therefore, will not support a shorter model time step. The model will be operated for the period 1960 to present.

Task 6.3 Data Preparation for Input to HPSF Model

Hydrologic models, like HSPF, require the input meteorological data to be continuous for the full period of simulation (i.e., no missing values). Furthermore, the data must be homogeneous (i.e., must not contain any systematic errors). Systematic errors in precipitation values, for example, can result from the growth of vegetation around a gauge or from periodic relocation of the gauge.

To meet the criteria of continuous and homogeneous data, the input meteorological records will be subject to a two stage process. Firstly, estimates will be made for missing pieces of data within the records. This will most often be done using a linear regression with the data of adjacent stations. Only short spells of missing data will be patched (i.e., infilled with estimated values). If long breaks exist, then the entire record will be rejected.

The second form of processing will be to check the meteorological records for systematic errors using double-mass plots. Any records with significant errors will not be used in the modelling work.

Task 6.4 Setup of HPSF Model

Inputs to the model will comprise calibration parameters, geometric data, hydrometeorological data, point source abstractions and discharges, areas under irrigation, and initial conditions. The setup of the model will involve creating the required input files and importing the hydrometeorological data into the file management system (known as WDM files).

Most of the model parameters will be estimated during the calibration process. However, the model parameters controlling the generation and transport of sulfate from the scar areas will be specified using empirical relationships derived from the coupled findings of Task 2 above and the Background Characterization Study. As described in the discussion of Task 2.5, empirical relationships will be derived that relate model parameters to the degree of geochemical activity within the particular scar area. This degree of activity will be quantified using a number ranking system from 5 (severe ARD load) to 5 (mild ARD load).

Task 6.5 Calibration of Flow Model

The calibration parameters controlling runoff generation will be adjusted until a satisfactory agreement is achieved between modelled and observed runoff records. The calibration will be carried out at six locations in the Red River basin where the USGS has operated a streamflow gauging station. To assist in modelling the snowmelt component of the stream hydrographs, the model will also be made to reproduce the development and ablation of the snowpack, as observed at local snow course stations.

During calibration of the flow component of HSPF, the following specific sequence of steps will be performed to achieve the best fit between modelled and observed records:

- minimize difference between observed and modelled long-term discharges;
- achieve a good fit with the observed annual standard deviation of flows;
- achieve a good fit with the observed seasonal distribution of average flows; and,
- adjust the shape of the daily hydrograph using parameters that control lag and attenuation.

To demonstrate the adequacy of the calibration, a table will be created showing various statistics for the observed and modelled streamflow records for the period of overlap. The statistics will include: the long-term average discharge, the standard deviation of annual flows, and the linear correlation coefficient. Also plots of daily modelled and observed flows will be created. This should show that the modelled and observed peaks and troughs coincide reasonably well in both magnitude and time.

Task 6.6 Calibration of Conservative Load Model

HSPF contains a set of process algorithms for simulating the washoff of conservative constituents from pervious areas and then routing these constituents through a network of stream reaches. These algorithms will be employed to simulate the generation and transport of sulfate through the Red River basin.

The calibration of the water quality component of HSPF will only occur once a satisfactory calibration with flow is achieved. In the water quality calibration stage, the main objectives will be to minimize differences between observed and modelled average sulfate loads and sulfate concentrations. It will be necessary to maintain a reasonable balance between initial and final storages of available sulfate within the various subbasins of the Red River in order to ensure that the simulated loads are representative of a stable regime.

The results of the sulfate modelling will be graphically illustrated on a flowsheet of the entire Red River basin.

Task 7 below describes a program aimed at evaluating the behaviour of reactive constituents in the Red River during baseflow conditions. After Task 7 has been substantially completed, the HSPF model will be evaluated for its suitability to generalize the results obtained from the reactive modelling. If deemed suitable, HSPF will then be used to estimate loadings of reactive constituents during non-baseflow periods and over long time scales. In effect, this would mean that calibration parameters could be selected that implicitly account for the reactive behaviour in at least an approximate way.

Task 6.7 Simulation of Closure Scenarios

Once Tasks 6.5 and 6.6 have been completed, a model will be available that represents the historical hydrology and water quality regimes of the Red River basin for the period 1960 to 1999. Changes to the calibration parameters and other input data can be made to simulate conditions other than those experienced historically. For example, the model can be used to estimate what the flows and water quality would have been over the period 1960 to 1999 if a constant level of land use had existed over that period (e.g., same area under irrigation, the same level of abstraction for the mill supply, and the same remediation measures at the mine area). Changes can also be made to the calibration parameters for certain areas within the Red River basin in order to simulate different flow and contaminant generation mechanisms. For example, the calibration parameters for the mine area can be replaced with values that represent the generation of flow and sulfate from natural scar areas. HSPF could then be run with these modified parameters to approximate pre-mining conditions.

Given the flexibility of the model, the following scenarios will be simulated using HSPF:

- present-day conditions (i.e., same model parameters derived through calibration but with a constant level of land use);
- pre-mining conditions (i.e., same calibration parameters for all subbasins of the Red River basin except for the mine area, which will use parameters deemed to be representative of natural scar areas, and the tailings area, which will use parameters representative of background conditions);
- future conditions under various closure measures (i.e., same calibration parameters for all subbasins of the Red River except for the mine area and the tailings impoundment area, which will use parameters deemed representative of the given closure measures); and,
- future conditions under a do-nothing scenario (i.e., provide only a minimal set of closure measures for the mine development).

All of these simulations will span the period 1960 to 1999. The pre-mining simulation would retain the variable land use observed over the 40-year simulation period. The future simulation, on the other hand, will be simulated at a constant level of land use. These simulations can be used, in an approximate way, to apportion loadings observed in the Red River to the various sources within the river's basin (i.e., mine, scar areas and other anthropogenic sources). For example, the results from the pre-mining simulation can be subtracted from the results of the historical simulation (i.e., the calibrated model) to obtain an estimate of the net impact of the mining operation, both on flows and on conservative constituents.

Another combination would be to subtract the "do-nothing" simulation from one of the future simulations to evaluate the net effect of the simulated closure measure.

Task 7 Reactive Load Model for Red River Basin

One of the objectives of this Comprehensive Water and Load Balance Study is to develop a firm understanding of chemical loading within the Red River basin and the degree to which water quality is regulated and affected by natural as well as mining-related metal sources. Due to the complexity of the surface water environment, this understanding can be enhanced by the use of numeric transport models. Many of the constituents in the Red River of environmental concern are non-conservative, including Fe, Al, Zn, Cu, Cd and others. In order to model pre-mining, current and post-closure concentrations of these reactive constituents a model is required which can represent the critical chemical reactions and transformation processes which regulate concentrations of these metals in the stream water and underlying benthic pore water. This task will be supported by load models developed for background areas (Task 2), the mine area (Task 3), the tailings area (Task 4), the groundwater in the Red River alluvium (Task 5) and for conservative constituents in the Red River (Task 6).

The modeling framework for describing non-conservative metal transport, transformations and fate in the Red River is the model, META4, which is part of the Water Analysis Simulation Program (WASP4, Ambrose et al. 1993). This model is a box-type modeling system consisting of a generalized transport model and three kinetic sub-models, EUTRO4, TOXI4, and META4. The WASP4 modeling program has a long development and application history. The WASP4 modeling system was developed by the U.S. Environmental Protection Agency for assessment of the transport and transformations of conventional pollutants and toxics in a variety of waterbodies. The hydraulic transport in WASP can be descriptive or can be derived by linking WASP with hydrodynamic models. The Metal Exposure and Transformation Assessment (META4) Simulation Program is a generalized metals transport, speciation, and kinetics model. It was developed for water quality simulation in a variety of receiving waters experiencing metals contamination, including ponds, streams, rivers, lakes and reservoirs.

META4 will be used to simulate the transport and fate of selected non-conservative metals (including Al, Fe, Zn, Cu, Cd) in the Red River in the reach between the town of Red River and the Ranger Station. The reactive transport modeling will focus on base flow conditions the time period of greatest environmental concern due to minimum dilution by snowmelt runoff.

Task 7.1 Data Review

The following data will be compiled and reviewed:

- historical hydrologic information for the Red River and tributaries (from Red River to Ranger Station) including but not limited to flows, rating curves, stream slope, channel dimensions;
- water quality data at various locations within the basin;
- sediment data from the main stem and any impoundments created from Red River water, including any data on metal precipitates and coatings within the system; and

- annual, seasonal and storm loading information on metals and other inorganics within the Red River, its tributaries or identified sources.

Based on this review a conceptual model will be developed for contaminant and major ion source, transformations, transport and fate within the Red River including the role of critical transformation processes in regulating both water and sediment quality. This conceptual model will be used to assess the completeness of the field monitoring program to generate sufficient information for the subsequent modeling task.

Task 7.2 Field Installation and Monitoring

The surface water monitoring program will include up to four rounds of sampling representing distinct seasonal periods to best characterize the river water quality. Dates of sampling will be selected based on a review of existing stream water quality surveys in the Red River. The periods of interest will include pre-runoff, the falling limb of the runoff hydrograph, late summer base flow and winter base flow through November, 2000. The sampling program will include seven main stem stations and up to twelve tributary or point loads to the river. The sampling proposed for the late summer period (mid-August to mid-September) will be more intensive than the other three periods due to the collection and characterization of the benthic environment (sediments and pore water).

Surface waters in the Red River will be sampled from the upper basin (abandoned gage near Zwergle Dam) downstream to the gage below the mine at Questa (Eagle Rock campground). Sampling of tributaries which either have the potential to contribute metals or dilution water to the Red River will be sampled during each monitoring period. Sample sites will include all sampling locations on Red River which were used in the previous investigation by Allen et al. (1999) to allow comparison between data sets. Each of the selected locations will be checked for consistency, appropriateness, access and safety during a site reconnaissance conducted prior to the field sampling activity. Specific rationale for modifying the locations of any sampling location relative to project objectives will be provided to the government agencies (NMED and MMD) prior to the commencement of field sampling activities.

<u>Surface Water Sampling.</u> Surface water sampled from the main stem and tributaries will be sampled synoptically based on estimates of the time-of-travel between sample locations. Prior to surface water sampling, a slug tracer study will be used to determine travel times and also be used to determine the longitudinal dispersion coefficient for use in modeling. All water samples will be taken at a time when there has been no measurable precipitation for at least 72 hours to ensure that samples are obtained under ambient, stable-flow conditions. This will aid in the comparison between data sets and in the reactive modeling. In the case that a sampling session is interrupted by a storm, sampling will be resumed only after 72 consecutive hours of dry weather has passed or flows have returned to pre-storm rates as determined by discharge measurements.

During the sampling session, five aliquots of each sample will be collected for laboratory analysis (total metals, dissolved metals, cations, anions and dissolved organic carbon). Parameters which will be measured in the field include water temperature, pH, redox, specific conductivity, and flow rate. Water sample will be collected synoptically using EDI or EWI depth integrating methods whenever possible (USDI, 1977). If this method cannot be used, then the stream segment will be divided into four approximate equal flow segments and subsamples will be collected and composited. For very small and narrow flows, a single sample from as near the center of the stream channel as possible will be collected using a clean plastic bucket, and brought back to the field vehicle. Water samples will be analyzed for the same suite of parameters as in the recent investigation by Allen et al., 1999.

Flow rates at all Red River sites will be determined using the mid-section method of discharge calculation for partial sections (Feldt, 1987) unless an operating USGS gaging station is available. Anywhere that the above method cannot be used on small tributaries, a calibrated bucket, portable flume, or simplified Marsh-McBirney measurements may be made.

Sediment Sampling. Prior to collecting sediment samples for mineralogical, physical and chemical analysis, a physical evaluation of various environments including the stream channel, stream depositional areas, and the stream bank will be completed. The evaluation at each of the sample locations will include a description of the flowing portion, dominant sediment characteristics, depositional or erosional (cobble area, boulders, gravels areas, sands/silt), eroding wastes, vegetated condition of bank, degree of cementation, and the velocity at several locations.

Sediment samples will be collected at each surface water location to determine the total metal content and readily exchangeable fractions. Two 250 mL samples (particle size < 2mm, sieve using creek water) will be collected as a composite (three locations) from depositional area and from the main channel. Sediment data will be used to evaluate chemical transformations in the creek, metal availability and potential toxicity. Volumes and sampling procedures may be modified following the in-depth sediment reconnaissance to evaluate local conditions with all changes in sediment sampling approved by the government agencies (NMED and MMD).

Sediment analyses will include physical parameters (particle size and porosity) and chemical parameters (mineralogical characterization, total metals, extractable anions, sequential extractions). The physical parameters which are of primary importance to fate and transport of sediment-associated metals are related to both the sorption characteristics of the sediments and the diffusion rate between surface water and porewater. These parameters include grain-size distribution, surface area per unit volume, porosity and permeability. Surface area and grain-size distribution are related, and directly effect the sorption characteristics of the sediments, which in turn control the porewater chemistry. The porosity and permeability of the sediments dictate to what extent the porewater and surface water chemistries are interdependent by controlling the exchange rate.

Grain-size distribution is easily measured by sieve analysis, and surface area can be estimated from the grain size distribution. However, porosity and permeability data may be difficult to measure directly due to the coarse, cohesionless nature of the stream sediments. Permeability measurements may be attainable through in-situ falling-head permeability tests, although difficulties may prevent accurate measurements. Direct porosity measurements will not be attainable due to the difficulties of retrieving undisturbed sediment samples in coarse, cohesionless sediments. Therefore, porosity will be estimated by comparing weights of saturated and dry sediment samples before sieve analysis.

Samples will be analyzed to determine the total metal concentration and the concentration of anions which may affect the fate and transformations of metals, including phosphate, sulfate, organic carbon and carbonates. Total metal determinations may be included in the analysis of sequential extractions.

X-ray Fluorescence (XRF), XRD and/or thin-layer electron spectroscopy will be used to characterize the mineralogy of the sediments. Efforts will focus on the composition of coatings on surfaces such as iron and manganese oxides which act as sorption surfaces, mineral phases of the contaminants of concern (Cd, Cu, Mn and Zn), and other potential precipitates such as aluminum hydroxides and magnesium carbonates. These solid phases may effect the chemistry of the porewater through sorption and coprecipitation.

Sequential extractions have been used successfully by several investigators to define the distribution of metals in various phases in sediments (Forstner, 1990). Up to five extractions will be required to define the distribution of the contaminants of concern in solid phases representing the following fractions: ion exchange, carbonates, iron/manganese oxides, sulfides/organics and residual phases. A few (3 or 4) initial samples will be subjected to all five extractions to define the phases which contain significant portions of metals. The remainder of the samples will only be subjected to the relevant extractions defined by the initial samples. It is anticipated that only two or three extractions will be necessary, including the residual. Sequential extractions will provide the remaining data necessary to simulate sorption and co-precipitation of metals to sediments in the Red River using a chemical equilibrium model such as MINTEQA2 and the diffuse-layer sorption routine as contained within the WASP4/META4 model.

<u>Pore Water Sampling</u>. Pore water chemistry data are essential to understanding the sediment-surface water interactions in the Red River and interpreting the geochemical modeling results. Without a clear understanding of these interactions, estimates of pre-mining and post-closure effects may be in error, particularly actions which do not result in the removal of contaminated sediments. Sampling of pore water will be carried out in-situ with dialysis bags housed in slotted Polycarbonate tubes buried in the sediments to a depth of 15-20 cm. It may be desirable to collect two samples at each sampling location; one for measurement of field parameters and one for laboratory analyses. The dialysis bags will then be retrieved after sufficient time has passed to allow equilibration between the sample bag and the pore water. Results should be representative if the sediments are allowed to

equilibrate for 7-10 days. Pore water will be analyzed for anions, nutrients, carbon, metals and field parameters (pH, redox, temperature, specific conductance, dissolved oxygen).

It is crucial that general characteristics of the field conditions be measured at the time of sample collection. Temperature, redox potential (Eh), dissolved oxygen, pH, and specific conductivity are all easily measured in the field.

Task 7.3 Setup of WASP4/META4 Model

The User Manual should be consulted for additional details on model theory and capabilities, input file creation and example model run files (Martin and Medine, 1998). The manual describes a newer model version, META4 Version 3, but is generally applicable to the previous versions. As all features of the previous versions have been fully incorporated into META4 Version 3, older versions are not currently supported.

A number of physical and chemical processes affect the transport of metals including advection, dispersion, chemical reaction, adsorption, desorption, erosion, sedimentation, precipitation, and dissolution. The modeling process will involve the evaluation of site data including the following:

- Dominant chemical reactions and matrix
- Boundary conditions
- System geometry and compartment flows
- Reaction constants
- Static parameters
- Target chemical loadings, both diffuse and point
- Flow regime and sediment characteristics

Model input data include volumetric flows, metal loading rates, and inflow metal concentrations. Other data needs include calculation time step, model segmentation, cell volume, channel geometry, volumetric flowrates, speciation reactions, and metal-sorbent reaction constants. The data collected in the basin during 2000 will be used in the calibration process. While assumptions are always necessary for certain data input for the model, the careful and thorough evaluation of existing data and the focused field monitoring proposed for 2000 will minimize the need for numerous assumptions which could affect the accuracy of the model for water quality projections for the Red River.

More complex sediment modeling, as used within META4, requires a delineation of the importance of dominant mechanisms which affect accumulation of metals in sediments and potential releases of metals from sediments. The accumulation of metals in sediments generally includes five major mechanisms:

1) Adsorption onto fine-grained materials, including oxides

2) Precipitation of trace element compounds

3) Co-precipitation with hydrous Fe, Al and Mn oxides and carbonates

4) Association with organic matter (adsorption or organometallic bonding)

5) Incorporation in crystalline minerals.

The sediment characterization activities planned for 2000 will determine the most active of these mechanism(s) with respect to metal transport and fate. Previous work at other mining sites has indicated that the most active of the sediment accumulation processes was the adsorption/desorption of metal to iron oxides. Under the current conditions and in future scenarios, it is likely that the role of oxides in regulating metal concentrations will remain the dominant process, even in the Red River. Measurement of pore-water characteristics and metal concentrations as well as characterization of sediment mineral phases to be performed during this investigation will allow a better estimation of active sorption surfaces. This data will then be used to apply the equilibrium-based, mass-balance modeling as contained in META4, to the Red River system in order to estimate the significance of sediment-water interactions and non-point source inputs of dissolved metals (i.e., groundwater accretion to the river). Results of Tasks 2.5 and 6.6. will provide important information for the application of META4 to the Red River.

The model configuration will include iron, aluminium, manganese, zinc and copper as state variables representing metals of interest. The final selection of state variables will occur following Task 7.1 – Data Review. The major parameters used to describe the speciation of metals, and the corresponding effects on sorption and desorption by the sediments generally include H^{+}, CO_3^{2-}, Ca^{2+}, SO_4^{2-}, Mg^{2+}, and Cl^{-}, and, up to three classes of adsorbing solids (Solids1-3, Solid1 generally represents iron oxides). The reactions included in the META4 submodel for WASP4 will be determined after a series of chemical speciation calculations on a wide variety of samples representing the main stem, tributaries, groundwater quality and other loads to the system. The speciation model selected for determination of the dominant chemical reactions affecting the speciation of zinc and cadmium is MINTEQA2 Version 3.11, released in December 1991 by the EPA's Center for Exposure Assessment Modeling at the Environmental Research Laboratory in Athens, Georgia (Allison et al., 1991). Chemical speciation reactions in the META4 submodel will be corrected for ionic strength using the Davies Equation as contained in MINTEQA2.

The META4 model for this portion of the Red River Basin begins near the headwaters (abandoned gage near Zwergle Dam) and ends at the downstream gage below the mine at Questa (Eagle Rock campground). The model will include numerous surface water segments along the main channel of the Red River along with the corresponding benthic segments for each water column segment. The detailed model segmentation represents the relationship between water column and bed region segments, the major point and nonpoint loads into each segment and the flow directions, including the interaction with the alluvial system. Model segments will be developed from information concerning the physical and chemical characteristics of stream reaches (i.e. slope, hydrology, sediment type) and locations for loads to the system, whether diffuse, tributary or point loads. Each water column is directly coupled to a benthic segment.

The specification of overall model details including control parameters, system configuration, hydrology, boundary conditions and loadings are provided in Data Groups A through J within the model as follows:

- **Data Group A** supplies model identification information and contains simulation control options. The user specifies the number of segments and the number of systems along with print interval and time steps.

- **Data Group B** contains dispersive exchange information between segments and along a characteristic length.

- **Data Group C** supplies initial segment volume information

- **Data Group D** supplies flow and sediment transport information between segments. Flows may be constant or variable.

- **Data Group E** supplies concentrations for each system at the boundaries. All system concentrations must be supplied for each boundary.

- **Data Group F** defines the waste loads and segments that receive the waste loads for both point and diffuse sources.

- **Data Groups G and H** provide details concerning the environmental characteristics and metal speciation and transformation processes, respectively.

- **Data Groups I and J** provide environmental or kinetic time functions as well as the initial conditions for each segment and system in the model, respectively.

Task 7.4 Calibration of Reactive Load Model

Following the detailed specification of system geometry, boundary conditions and initial conditions, the model will be calibrated to one of the data sets collected during 2000. It is anticipated that the August-September period will represent the main calibration data. Because of the complexity of reactive chemical transport, a step-wise approach is taken to allow the calibration process to proceed in an orderly fashion. Following the balancing of flows within the river system, conservative parameters are next balanced. Following the successful balancing of conservative parameters, the calibration proceeds to balance the non-conservative variables with the observed data. An error analysis is included to determine the accuracy of the calibration and estimates of model uncertainty. Following the calibration, an additional data set will be used to evaluate model confirmation. The data to be used would represent an independent data set collected either before or after the calibration data set.

Task 7.5 Simulation of Pre-Mining and Post-closure Scenarios

Following the successful calibration-confirmation process, the model will be used to evaluate pre-mining conditions and post-closure scenarios. Through the modification of the model inputs (loads, flows and concentrations), whether from tributaries, groundwater or surface runoff from naturally mineralized or mining disturbances, the conditions of the Red River representative of the pre-mining scenario will be estimated with the model. These results will be used along with the post-closure activities and the resulting load reductions to determine the future water quality which would be anticipated following closure activities.

4 SCHEDULE AND DELIVERABLES

The schedule for the proposed work plan is shown in Table 2 (modified from Tables A1 and A2 in Appendix A submitted earlier). The deliverables and dates of submission are summarized in Table 3.

5 REFERENCES

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Tables

Table 1 Summary of Models to be developed for Water and Load Balance Study

Model No.	Numerical Model used	Model Developer	Type of model	Area that model is to be applied to	Model time step	Period covered by modelling
1	HSPF	USEPA & USGS	Deterministic hydrologic and water quality model	Each of the three selected basins for the Background Characterization Study (i.e., Hanson, Strait, and Haut-N-Taut Creeks)	1 to 3 hours	Approximately Mar. to Oct. 2000
2	Spreadsheet	To be developed	Mass balance	Mine site, including new and old underground mine developments	Annual	1965 to 1999
3	Spreadsheet	To be developed	Mass balance	Tailings impoundment	Annual	1965 to 1999
4	MODFLOW/MODPATH (or finite-element model)	USGS	Groundwater flow model	Mine site	Steady-state	Present-day conditions
5	MODFLOW	USGS	Finite-difference groundwater flow model	Tailings impoundment	Steady-state	Present-day conditions
6	MODFLOW/MT3D	USGS	Finite-difference groundwater flow and transport model	Reach of Red River between mill site and Questa Ranger Station	Steady-state	Present-day conditions
7	HSPF	USEPA & USGS	Deterministic hydrologic and water quality model	Entire Red River basin	Daily	1960 to 2000
8	META4	USEPA	Reactive surface water quality model	Reach of Red River between Town of Red River and Questa Ranger Station	Approximately 1/1000 of a day	Select baseflow conditions during the period 1965 to 2000

Table 2. Schedule for Comprehensive Water and Load Balance Study

Task	Description	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	
1	Regional Hydrology Study																							
1.1	Precipitation Analysis																							
1.2	Evaporation Analysis																							
1.3	Runoff Analysis																						Dec 15	
2	Load Model for Background Watersheds																							
2.1	Data Review																							
2.2	Conceptualization of Flow and Transport																							
2.3	Setup of HSPF																							
2.4	Calibration of Flow Model																							
2.5	Calibration of Conservative Load Model																							
2.6	Calibration of Reactive Load Model																						Dec 15	
3	Load Model for Mine Area																							
3.1	Data Review																							
3.2	Development of Mine Water Balance																							
3.3	Groundwater Flow Model																							
3.4	Development of Conservative Load Model																							
3.5	Development of Reactive Load Model																						Dec 15	
4	Load Model for Tailings Area																							
4.1	Data Review																							
4.2	Development of Tailings Water Balance																							
4.3	Review and Update of Groundwater Flow Model																							
4.4	Development of Conservative Load Model																							
4.5	Development of Reactive Load Model									May 31														
5	GW Flow & Transport Model for Red River Alluvium																							
5.1	Data Review																							
5.2	Well Installation and Monitoring																							
5.3	Setup of Groundwater Flow and Transport Model																							
5.4	Calibration of Groundwater Flow and Transport Model																						Dec 15	

Table 2. Schedule for Comprehensive Water and Load Balance Study

Task	Description	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	
6	Conservative Load Model for Red River Basin																							
6.1	Data Review																							
6.2	Conceptualization of Flow and Transport																							
6.3	Data Preparation for Input to HSPF Model																							
6.4	Setup of HSPF Model																							
6.5	Calibration of Flow Model																							
6.6	Calibration of Conservative Load Model																							
6.7	Simulation of Closure Measures																							**Dec 15**
7	Reactive Load Model for Red River Basin																							
7.1	Data Review																							
7.2	Field Installation and Monitoring																							
7.3	Setup of WASP4/META4 Model																							
7.4	Calibration of Reactive Load Model																							
7.5	Simulation of Pre-mining and Post-closure Scenarios																							**Dec 15**

Code:

Report

Table 3. Deliverables for Comprehensive Water and Load Balance Study

Deliverable	Date of Submission
Report on Load Model for Background Watersheds	December 15, 2000
Report on Load Model for Mine Area	December 15, 2000
Report on Load Model for Tailings Area	May 31, 2000
Report on Ground Water Flow and Transport Model for Red River Alluvium	December 15, 2000
Report on Conservative Load Model for Red River Basin	December 15, 2000
Report on Reactive Load Model for Red River Basin	December 15, 2000

Figures

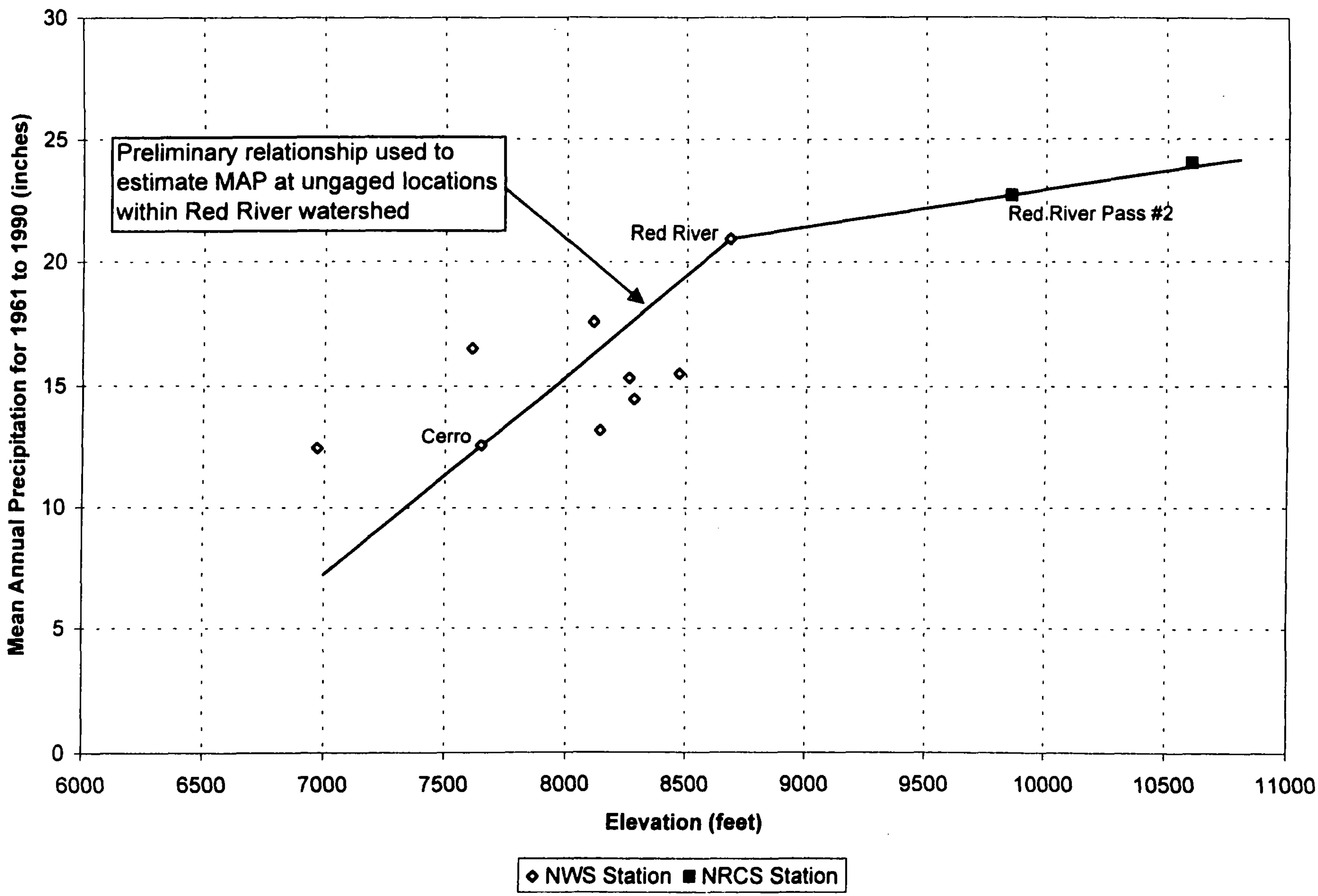


Figure 1. Regional Relationship Between MAP and Elevation

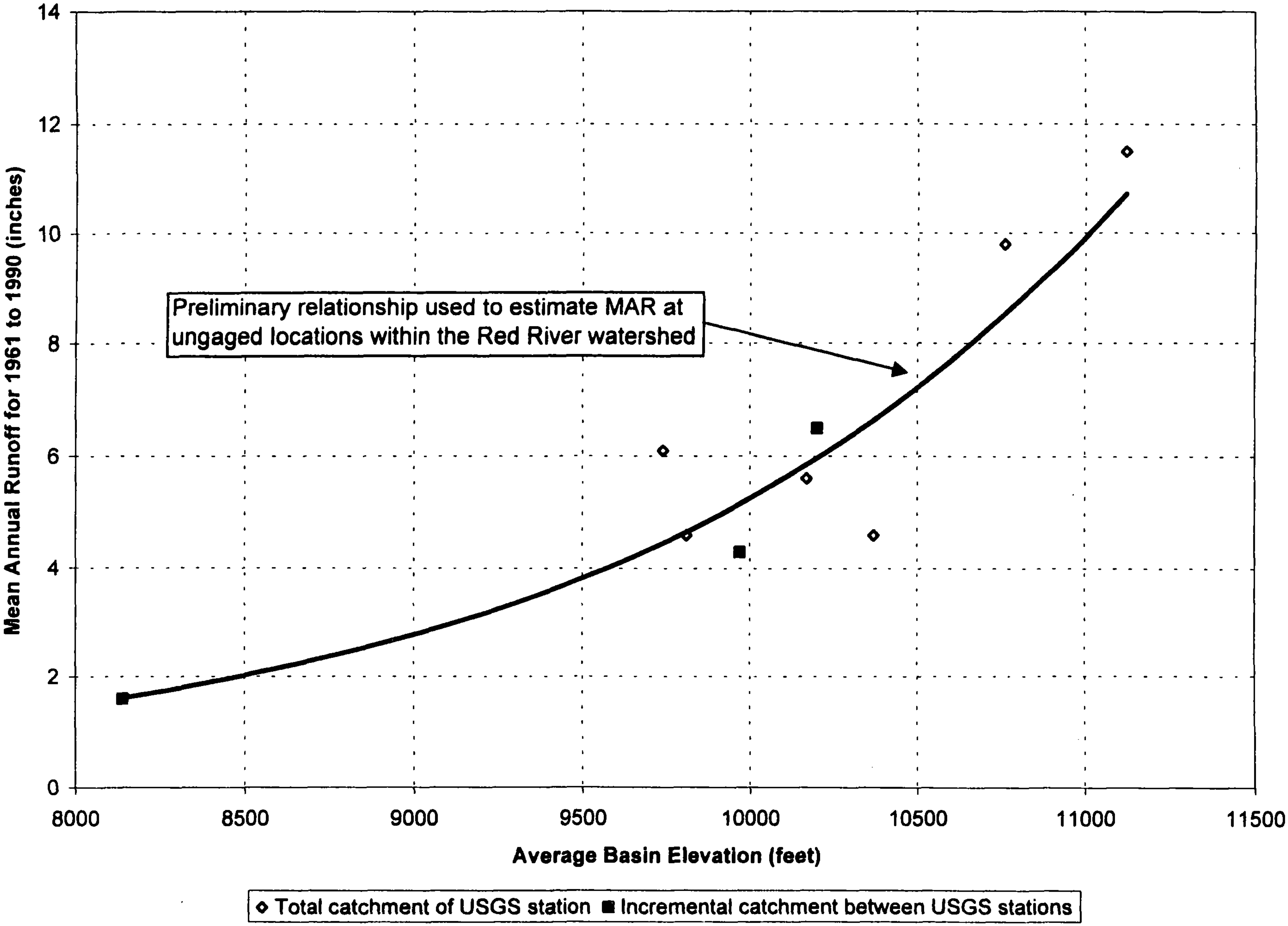
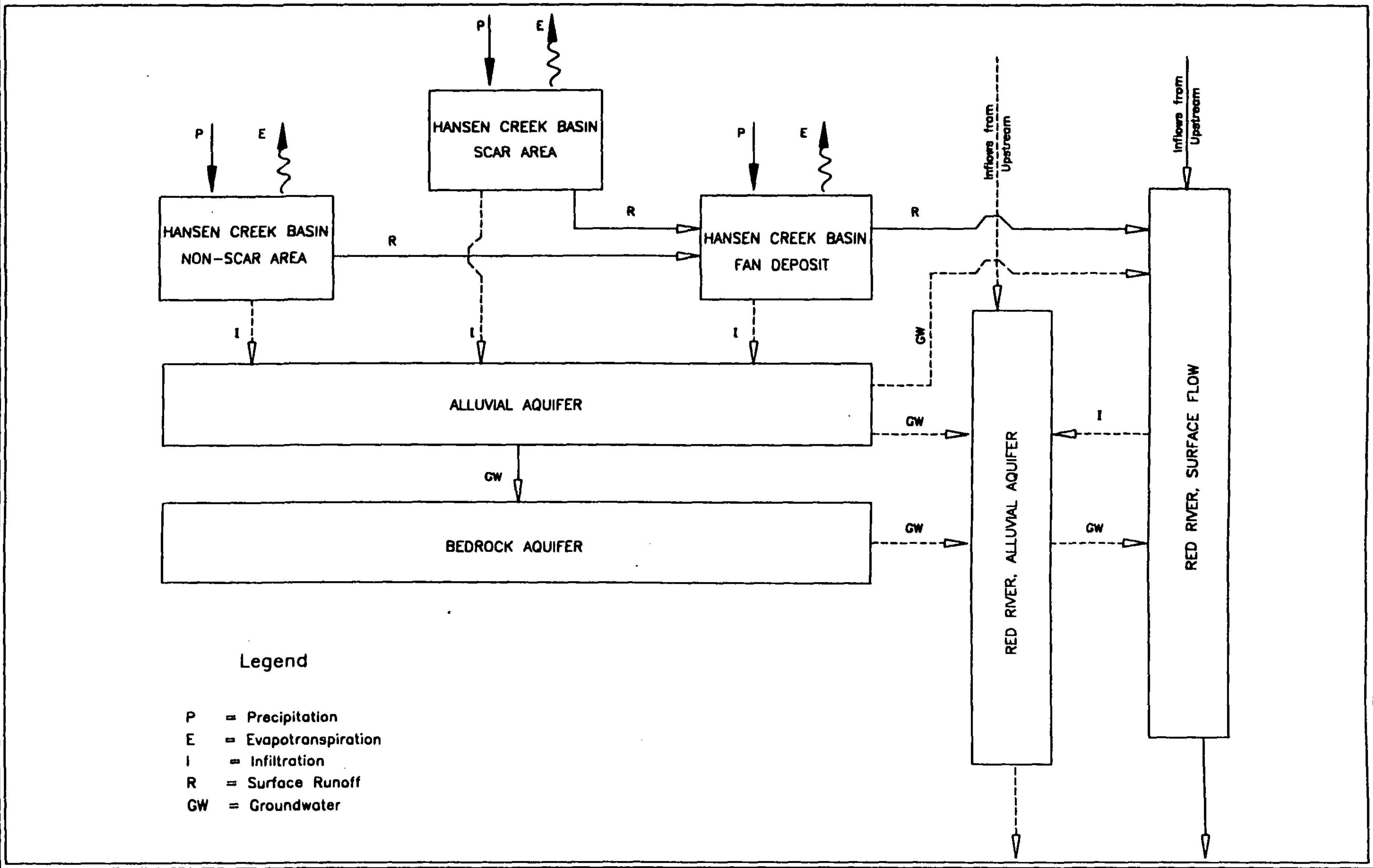


Figure 2. Regional Relationship Between MAR and Average Basin Elevation

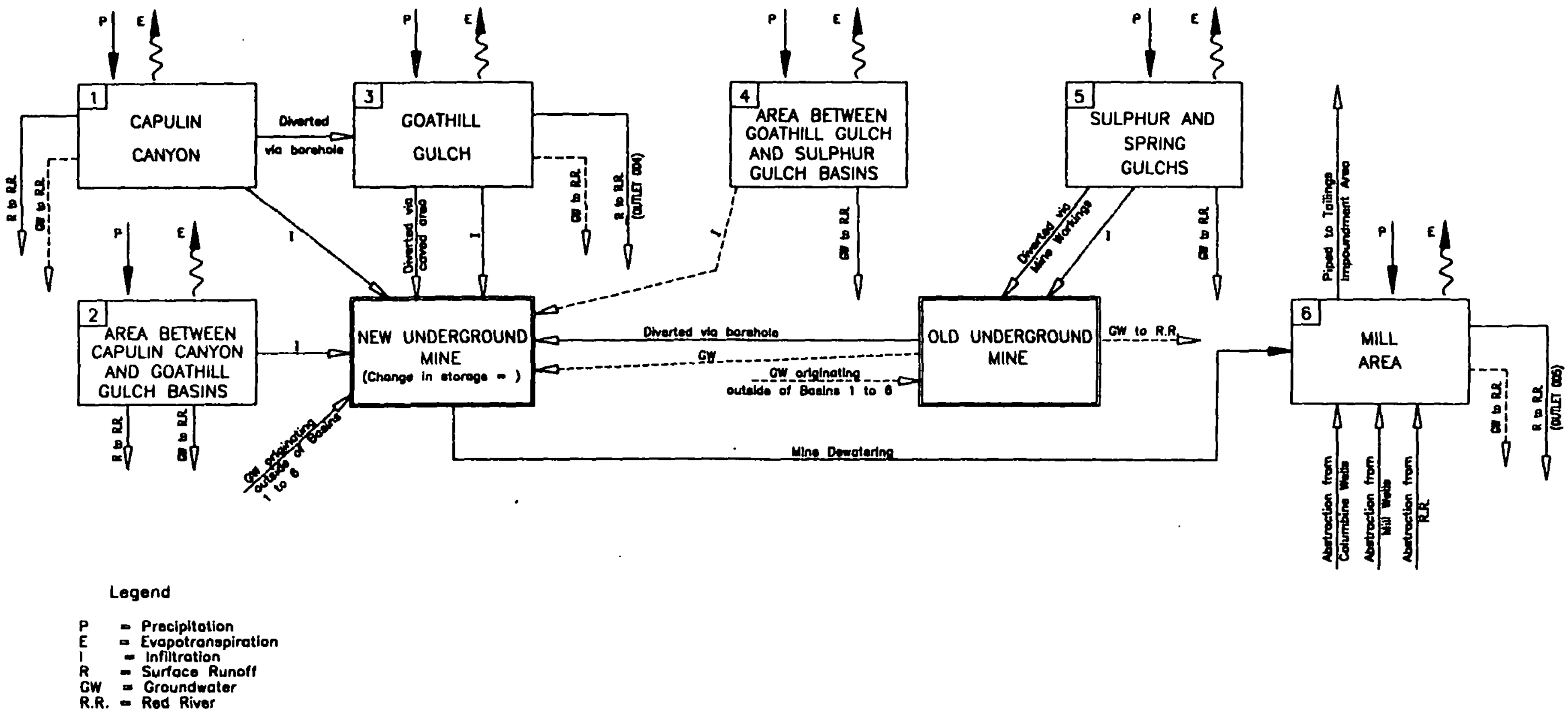


CLIENT:	MOLYCORP, INC.
PROJECT No:	052008
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Preliminary Flowsheet for Hansen Creek Water and Constituent Load Balances

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	3

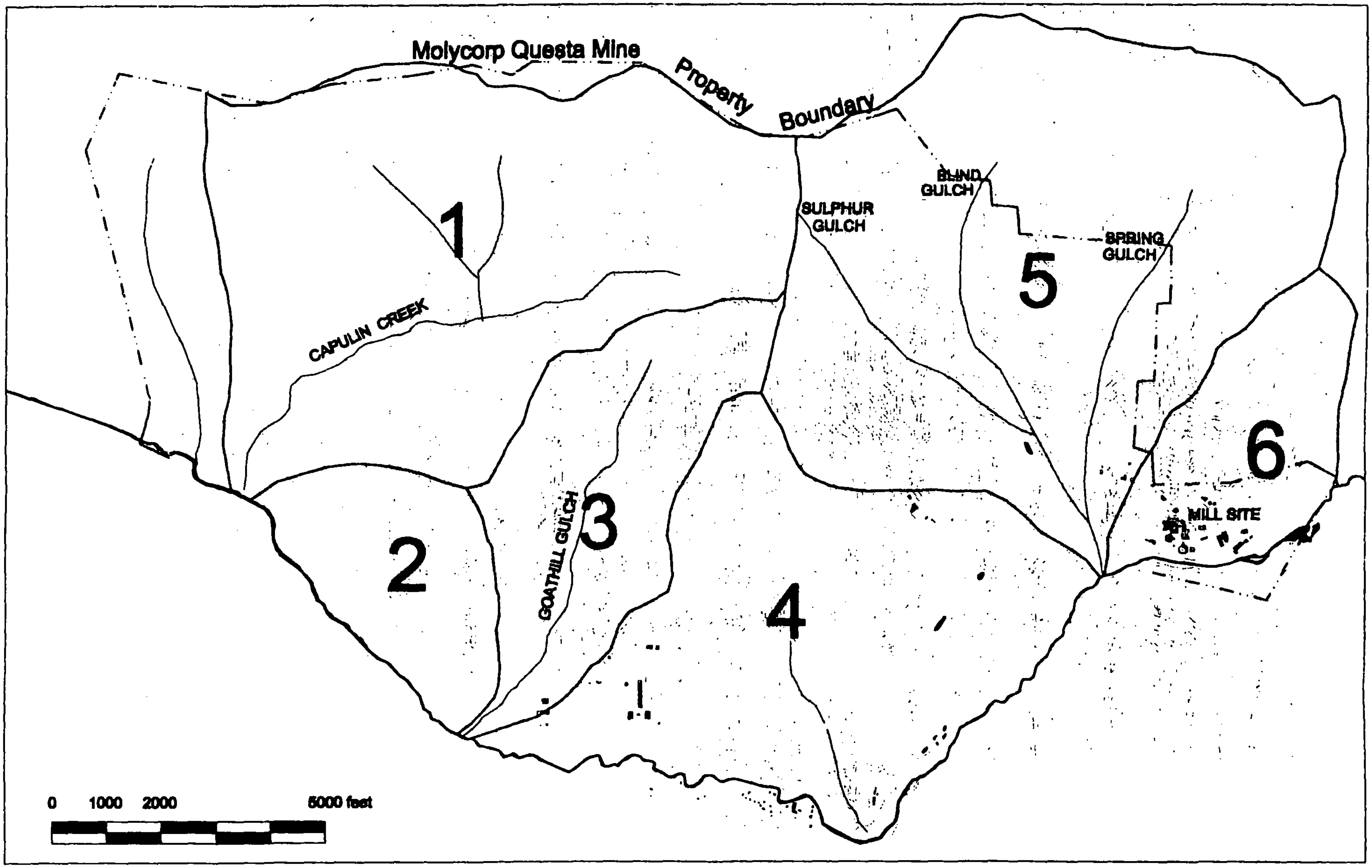


CLIENT:	MOLYCORP, INC.
PROJECT No:	052008
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Preliminary Flowsheet for Mine Site Water and Constituent Load Balances

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	4

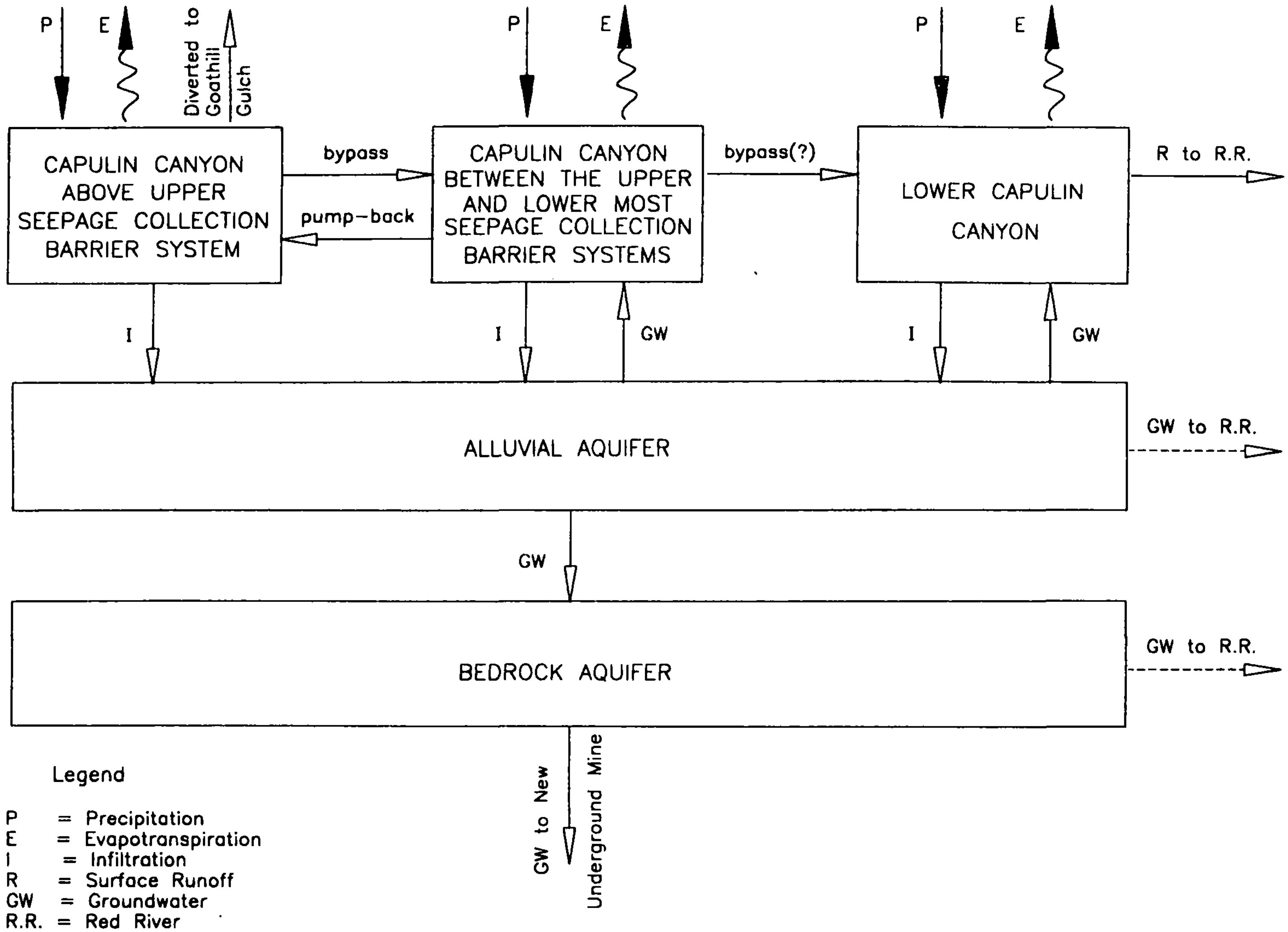


Legend

Basin boundary

1 Basin ID number

CLIENT:	MOLYCORP, INC.	ROBERTSON GEOCONSULTANTS INC. Consulting Geotechnical and Environmental Engineers	
PROJECT No:	052008	Mine Area Basins	
PROJECT:	QUESTA CLOSEOUT PLAN		
LOCATION:	QUESTA MINE NEW MEXICO, USA	DATE: Jan. 2000	DRAWN BY: JG
		FIGURE: 5	

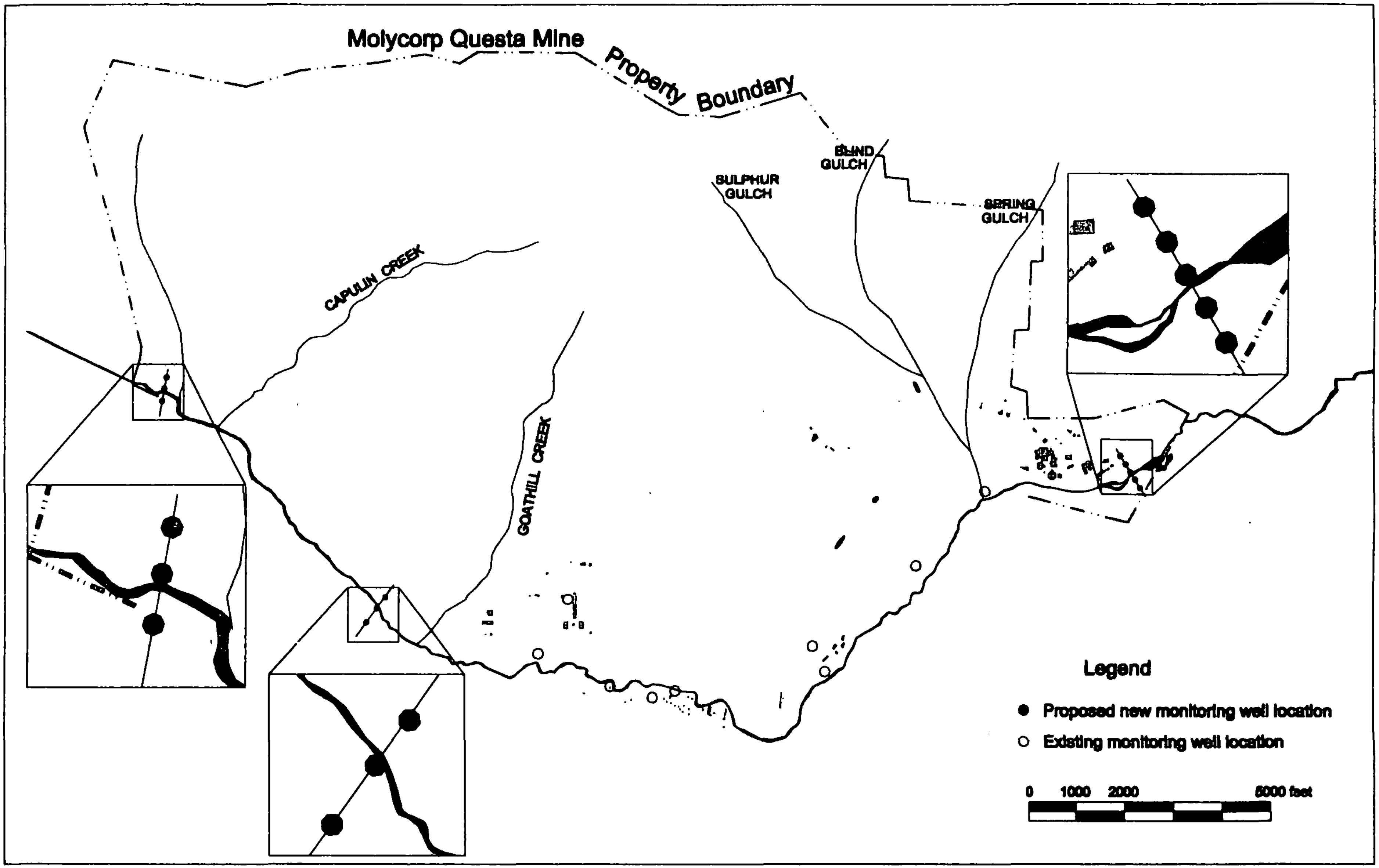


CLIENT:	MOLYCORP, INC.
PROJECT No:	052008
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Preliminary Flowsheet for Capulin Canyon Water and Constituent Load Balances

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	6



CLIENT:	MOLYCORP, INC.
PROJECT No:	052008
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Proposed New Monitoring Well Locations

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	7

Appendix A

Schedule for development of Closeout Plan for Questa Mine, New Mexico

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 1: Framework for Review & Submission of Closeout Plan for Mine Site																														
Technical Review Round 1: Characterization & Scoping																														
-TRC & MAA Planning Meeting				Jan 13-14 (projected)																										
-Background Data Summary																														
-Development Data Summary																														
-Detailed Work Plans																														
-Draft Outline of Closeout Plan																														
-Meeting									March 31 (projected)																					
Technical Review Round 2: Alternatives Evaluation																														
-Design & Assessment of Alternative Control Measures																														
-Meeting																							October 16-17 (projected)							
-Additional Design & Assessment of Alternative Control Measures																														
Initial WQA (NMED) Public Hearing on DP 1055										April 3 (projected)																				
Submission of Modified Preliminary Closure Plan to NMED																					September 29									
Technical Review Round 3: Closeout Plan Options Review																														
-Closeout Plan Options Development																														
-MAA Meeting																										December 14-15 (projected)				
-Final Closeout Plan Preparation																														
Submission of Closeout Plan																													January 31 2001	
Submission of Supplementary Report to Closeout Plan																														May 31, 2001
WQA (NMED) Public Hearing on Modification of DP 1055																														July 31, 2001 (projected)
NMMA (MMD) Public Hearing on Closeout Plan																														August 1, 2001 (projected)
Submission of Financial Assurance Proposal (MMD)																														Oct 30, 2001
NMED Determination on Closeout Plan																														Nov 30, 2001 (projected)
Public Hearing on Financial Assurance Proposal (MMD)																														Nov 30, 2001 (projected)
Anticipated Approval of Closeout Plan, Financial Assurance in place (MMD)																														Dec 31, 2001 (projected)

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

		Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 2: Work Tasks under DP1055 (Mine Site)																															
A	**Characterization and Monitoring**																														
A.1	**Waste Rock Characterization**																														
Phase 1	*Initial investigation*																														
Task 1.1	Review of mining history and mine records and determination of dump composition																														
Task 1.2	Site reconnaissance and mapping to define all sources (natural, mine disturbed and dumps)																														
Task 1.3	Phase 1 drilling and sampling program	C																													
Task 1.4	Instrumentation and monitoring	P																													September 2001
Task 1.5	Phase 1 static and kinetic laboratory geochemical testing program	P																													September 2001
Task 1.6	Phase 1 geotechnical/geohydrological testing program																														
Task 1.7	Phase 1 characterization and monitoring analyses and report									March 17																					
Task 1.8	Preliminary design and evaluation of closure measures																														
Phase 2	*Investigation and Testing Program*										March 31																				
Task 2.1	Phase 2 drilling and sampling program																														
Task 2.2	Phase 2 laboratory geochemical testing program																														
Task 2.3	Phase 2 geotechnical/geohydrological testing program																														
Task 2.4	Phase 2 characterization and monitoring analyses and report																				Aug 31										
Task 2.5	Design and evaluation of closure measures (Closeout Plan)																														Jan 31 2001
A.2	**Geophysical Surveys**																														
Task 1	Seismic and electrical resistivity profiles in vicinity of MMW-7																				Aug 31										
A.3	**Installation of Monitoring Wells**																														
Task 1.1	Installation of additional monitoring wells	C																													
A.4	**Infiltration of storm water runoff**																														

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

			Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
	Task 1.1	Continued sampling required by Molycorp's Storm Water Pollution Prevention Plan																														ongoing
	Task 1.2	Calculation of potential impact on ground water quality by storm water runoff																														
A.5	**Surface and ground water quality monitoring**																															
	Task 1.1	Monthly gauging of monitoring wells																														ongoing
	Task 1.2	Bi-annually sampling and water quality analysis																														ongoing
A.6	**Reporting of regular monitoring well data**																															
	Task 1.1	All available gauging and water quality results from the mine monitoring wells forwarded to	C																													
A.7	**Background Characterization Study**																															
	Phase 1																															
	Task 1.1	Reconnaissance survey						Jan 31																								
	Task 1.2	Historical and anthropological use determination																														
	Task 1.3	Surface water monitoring																														May 2001
	Task 1.4	Report on background characterization of surface water from non-mining scar affected areas																							Oct 16							
	Phase 2							Jan 31																								
	Task 2.1	Ground water reconnaissance survey																														
	Task 2.2	Ground water quality monitoring																														May 2001
	Task 2.3	Background characterization of groundwater from non-mining scar affected areas (w/ drilling)																	Jul 17													
	Task 2.4	Reconnaissance survey of all scar areas																														
	Task 2.5	Watershed baseline contaminant load model																											Dec 15			
A.8	**GSI/Water from the P-series of wells**																															
	Task 1.1	Submit data	C																													

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

		Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
A.9	**Report Submittals**																														
Task 1.1	Submit 1997 reports by TRC Environmental Solutions Inc., Schafer & Associates and Chadwick Ecological Consultants Inc.	C																													
A.10	**Water Balance for Waste Dumps**																														
Phase 1	*Water balance for three representative dumps*																														
Task 1.1	Select waste rock types; analyze soil characteristics; finalize design (with modeling) submit work plan for cover test plot construction	P							Feb 29																						
Task 1.2	Install plots and met station; set-up and data acquisition system																														
Task 1.3	Preparation of As-Built Report																June 30														
Task 1.4	Monitoring																														
Task 1.5	Initial review of model calibration, recommendation for changes (if required)																														
Task 1.6	Monitoring																														June 2001
Task 1.7	Calibration of soil-atmosphere model																							Oct 16							
Task 1.8	Water balance calculations																														
Phase 2	*Water balance for all dumps*																														
Task 2.1	Water balance calculations																											Dec 15			
A.11	**Comprehensive Hydrological Balance**																														
Phase 1	*Natural contaminated drainage site detailed hydrological balance*						Jan 31																								
Task 1.1	Surface water characterization and model																														
Task 1.2	Groundwater characterization and model																														
Task 1.3	Integrated geochemical load balance																											Dec 15			
Phase 2	*Mine detailed hydrological balance*						Jan 31																								
Task 2.1	Surface water characterization and model																														
Task 2.2	Groundwater characterization and model																														

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

		Completed	Schedule (01-Dec-99 to 15-Jan-01)	projected date of completion (if after January 31, 2001)
	Task 2.3 Integrated geochemical load balance		Dec 15	
	Phase 3 Tailings detailed hydrological balance(see Schedule for Tailings Facility)			
	Phase 4 Red River basin system description		Jan 31	
	Task 4.1 Surface water characterization and model			
	Task 4.2 Groundwater characterization and model			
	Task 4.3 Integrated geochemical load balance		Dec 15	
B	**Abatement of Existing Ground and Surface Water Contamination**			
C	**Contingency Plan**			
C.1	**Submittal of Contingency Plan**			
	Task 1.1 Submit plan (revisions to plan)	P	Aug 31	
D	**Closure Plan and Financial Assurance Plan**			
D.1	**Revegetation Program**			
	Task 1.1 Continue implementation and research program with Revegetation Success & Establishment Report			April 2001
D.2	***Closure Plan***			
	Task 1.1 Determine what, if any additional measures are required for the Closeout Plan		Sep 30	
D.3	**Post-Closure Hydrologic Model**			
	Task 1.1 Assess mine post-closure impacts to ground water and surface water			
	Task 1.2 Develop and refine dynamic hydrologic model			
D.4	**Interim Financial Assurance Plan**			
	Task 1.1 Provide financial assurance plan pursuant to Water Quality Act	P	Jan 14 (projected)	

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 3: Additional Studies for Close-Out Planning																														
E Additional Studies - Mine Site																														
Study E1 Surface Erosion & Stability Analysis (Work Plan, Investigation & Report)				Dec 31															Aug 16											
Study E2 Rooting Zone and Cover Evaluation (Work Plan, Investigation & Report)						Jan 31																	Oct 16							
Study E3 Borrow Materials Investigation (Work Plan, Investigation & Report)						Jan 31																	Oct 16							
Study E4 Wildlife Impact Study (Work Plan, Investigation & Report)								Feb 29																						April 2001
Study E5 Open Pit Waiver Information (Work Plan, Investigation & Report)						Jan 31																								April 2001
Study E6 Subsidence Area Waiver Information (Work Plan, Investigation & Report)						Jan 31																								April 2001
Study E7 Vegetation Test Plot (Work Plan)						Jan 31																								

Code:

▲ Workplan C Work Task completed ——— Duration of Specified Task

■ Report P Work Task partially completed — — Duration of Specified Task (weather permitting)

● Projected Meeting/Hearing

Note: Work Plan and report submittal dates are the dates of first submittal by Molycorp. It is assumed that no more than one month will be required after submittal for workplan or report acceptance.

Table A2. Schedule for development of Closeout Plan for Tailings Facility - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 1: Framework for Review & Submission of Closeout Plan for Tailings Facility																														
Questa Tailings Facility Revised Closure Plan submitted	■	**May 1, 1998**																												
WQA (NMED) Public Hearing on DP 933 Modification																		**July 31, 2000 (projected)**													
NMMA (MMD) Public Hearing on Tailings Closeout Plan																		**Aug 1, 2000 (projected)**													
NMED Determination on Closeout Plan																										**Nov 30, 2000 (projected)**				
Submission of Financial Assurance Proposal (MMD)																						**Sep 29, 2000 (projected)**								
Public Hearing on Financial Assurance Proposal (MMD)																									**Nov 15, 2000 (projected)**					
Anticipated Approval of Closeout Plan, Financial Assurance in place (MMD)																												**Dec 29, 2000 (projected)**		
Part 2: Work Tasks under DP1055																														
A Characterization and Monitoring																														
A.11 Comprehensive Hydrological Balance																														
Phase 3 Tailings detailed hydrological balance						**Jan 31**																								
Task 3.1 Surface water characterization and model	**P**																													
Task 3.2 Groundwater characterization and model	**P**																													
Task 3.3 Integrated geochemical load balance	**P**													**May 31**																
Part 3: Work Tasks under DP 933 (Tailings Facility)																														
A Characterization and Monitoring																														
Task A1 Tailings Revegetation (Work Plan, Investigation & Report)								**Feb 29**																						**April 2001**

Table A2. Schedule for development of Closeout Plan for Tailings Facility - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Task A2 Tailings Cover Test Plot Study (Work Plan, Investigation & Report)						Jan 31																								June 2001
Part 4: Additional Studies for Close-Out Planning																														
B Additional Studies - Tailings																														
Study B1 Surface Erosion & Stability Analysis (Work Plan, Investigation & Report)				Dec 31										May 31																
Study B2 Borrow Materials Investigation (Work Plan, Investigation & Report)						Jan 31								May 31																
Study B3 Wildlife Impact Study (Work Plan, Investigation & Report)								Feb 29						May 31																

Code:

- Workplan
- Report
- Projected Meeting/Hearing

C Work Task completed

P Work Task partially completed

Duration of Specified Task

Duration of Specified Task (weather permitting)

Note: Work Plan and report submittal dates are the dates of first submittal by Molycorp. It is assumed that no more than one month will be required after submittal for workplan or report acceptance.